Evaluation of Materials and Building Details for Sustainable Housing Reconstruction in the Gulf Coast of the United States

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1 Abstract

In August and September 2005, Hurricanes Katrina and Rita made landfall in the U.S. Gulf Coast, causing extensive damage to the housing stock in the area. This study examines four vital aspects of the housing reconstruction.

First, this study examines and evaluates residential building materials, both commonly used and “green,” using metrics in the categories of health, safety, cost, local issues, and green issues. Metrics considered in the local issues category include effects of water saturation, water permeability, mold resistance, termite resistance, presence in vernacular architecture, and cultural perceptions of the material. Metrics considered in the green issues category include recycled content and renewability, material emissions caused by its manufacture, potential for resource-efficient building strategies, whether it is locally manufactured, and thermal performance. The results of this evaluation are arranged in a user-friendly matrix for homeowners and builders.

One material, ThermaSAVE, is currently being used in the construction of demonstration homes in Houston, Texas, and Baton Rouge, Louisiana, by the Federation of American Scientists. ThermaSAVE is a panel building technology intended for use as the complete wall system. Each panel consists of two half-inch thick cementitious layers sandwiching a core of extruded polystyrene foam. Side-by-side diagonal load tests of ThermaSAVE panels and OSB structural insulated panels were conducted with panels soaked in water, panels exposed to humidity, and standard dry panels to examine the structural implications of flooding and rain. The comparison of these panel technologies allows us to focus on a family of products that may be used to build an energy efficient, safe home, with a short construction timeline. Since flooding caused much of the irreparable damage, it is important to test the structural performance of these panels after saturation. Joint tests were also conducted on the ThermaSAVE panels to determine issues that may be encountered in the field assembly of the panels.

Third, this study discusses building codes in the context of the Florida building codes, where recent code changes have dramatically reduced building damage and injuries from hurricanes.

The final element of this study was the evaluation of building details for fire, wind, rain, flood, moisture, and termites. The inclusion of building details in this study is crucial because the performance of an assembly of materials is not simply equal to the sum of its components. Based on the results of the materials evaluation, materials testing, and building code background study, this report recommends materials and building details that reduce the potential for hurricane wind, flood, and rain damage.

During the chaotic rush to rebuild housing in the devastated Gulf Coast area, it is difficult for homeowners, architects, planners, city, regional, and federal officials and others, to step back and re-evaluate building methods to prevent a recurrence of the damage from the 2005 hurricanes. Though much of the information on best practices for flood and hurricane construction already exists in the literature, we intend for this report to be a consolidation of industry knowledge that will help builders and homeowners make informed decisions in the reconstruction of the U.S. Gulf Coast.

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4 Introduction

4.1 Origins of this Study

This study was conducted as part of a graduate level course offered by the Energy and Resources Group in conjunction with the Department of Engineering at the University of California at Berkeley during the Spring 2006 semester. The course, "Design for Sustainable Communities," focused on sustainable technology research primarily for communities in developing countries. The idea for the course was conceived by UC Berkeley Engineers for a Sustainable World, and it was taught by Lawrence Berkeley National Laboratory (LBNL) scientist Ashok Gadgil, Ph.D. The core of the course was a series of in-depth engineering research and design projects, where student teams worked on part of an existing long-term technology research and design project. The student project teams were advised by a member of the existing project team.

As a result of recent natural disasters, including the earthquake in Afghanistan and Hurricanes Katrina and Rita in the Gulf Coast of the United States, our group chose to focus on a housing technology, hoping to address the need for extensive emergency housing in response to natural disasters.

Through the course, we were connected with Rick Diamond, Ph.D., of LBNL and Mileva Radonjic of the Federation of American Scientists, who were working with a panel construction technology called ThermaSAVE (Lee et al.). ThermaSAVE is a structural insulated panel technology, composed of polystyrene foam with external layers of fiber cement board, that is meant to be able to be assembled quickly, eliminating the need for any other wall layers. We decided to use part of our project to focus on this technology and best practices for its use in hurricane reconstruction in the Gulf Coast. We also evaluated other technologies and materials that are more commonly used in reconstruction efforts. This project is an effort to provide useful information to those engaged in the rebuilding effort. Though we have been careful to note the limitations of the material gathered in this report, we caution that these recommendations be reviewed and modified for specific applications.

4.2 Defining Sustainability

In order to structure our project with the goal of addressing sustainability in the reconstruction of the Gulf Coast, we first state our definition of sustainability. We have attempted to address the more traditional definition of sustainability in the environmental sense as well as a more local and event focused idea of durability. One frequent definition of sustainability is that it "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland). We are also adding to the definition the idea that as climate change effects cause the ocean temperatures to rise and increase the frequency of Katrina-like hurricanes, the definition of sustainability must also encompass the ability of the current population to sustain its existence in the same location as conditions change (Holdren).

4.3 Study Objectives

We elected to pursue four objectives in this four-month study: 1) the development of material matrices; 2) side-by-side ThermaSAVE and OSB panel testing; 3) examination and discussion of building codes; and 4) a review of select building details.

4.3.1 Material Matrices

Through discussions with building professionals, the Baton Rouge, LA, building inspection department and a Home Depot on the Gulf Coast, we came to the realization that even once the residents of the Gulf Coast overcome the seemingly insurmountable barriers to obtaining funding and approval to proceed with repair and reconstruction of their homes, there is a significant lack of knowledge of the advantages and disadvantages of various building materials in terms of both their environmental impact and a number of other locally important factors. Our materials matrices attempt to provide information on products in ten categories of structural and skin materials commonly used in single family detached residential construction with the intent of providing homeowners and builders with a central information source for their decisions.

4.3.2 ThermaSAVE Panel Testing

In order to address some specific questions we had about the performance of the ThermaSAVE panel technology, we elected to perform a number of tests that would first allow us to understand the difficulties that one might encounter in the common use of the panels, as well as address questions of how flooding and wind conditions may compromise the panel in comparison to oriented strand board (OSB) structural insulated panel (SIP). The following report discusses our methods, observations, and results.

4.3.3 Building Codes

During our materials research we became aware that our studies would have to include knowledge of the building code status in areas of the Gulf Coast. Though a much larger study could be done to assess the changes that will come about in various municipalities at different times through the rebuilding period, we simply wanted to get a sense of what the major building code and inspections are that are confronting the public during the rebuilding process

4.3.4 Building Details

As is true in many fields, the individual pieces are only half the battle. It is necessary to look at the assembly of the materials in order to successfully build sustainable structures. This section of the study examines a number of published building details to assess the advantages and disadvantages of each method of assembly, especially in the local context of flood, wind, rain, fire, termites, and humidity. We then took the findings from this research and summarized our observations into recommendations for the Federation of American Scientists about how to improve the details for the ThermaSAVE panel technology. We also include recommendations for future research and testing.

5 Background

In late August and early September 2005, hurricanes Katrina and Rita made landfall on the Gulf Coast, leading to one of the worst catastrophes in the history of the United States (Tierney).

Almost one year later, preparing for the next hurricane season, the region has barely recovered. As the citizens of the Gulf Coast work to reconstruct their buildings and communities in ways that will ideally withstand future storms, we aim to provide through this project one more resource that will aid in this enormous reconstruction. Though hurricanes will undoubtedly hit the same area again, we hope that the residents and government officials will learn from each occurrence, making the region less vulnerable to the same magnitude of destruction from future events.

5.1 The Gulf Coast Before the Hurricanes

The U.S. Gulf Coast is one of the poorest areas in the country. With poverty rates several percentage points above the national average, lower income than the national average, and a higher rate of homeownership on average, the area is exceptionally vulnerable to damage from floods and hurricanes ("U.S. Census Quick Facts"). The map below shows the FEMA-declared disaster counties as a result of Hurricane Katrina and their poverty rates.

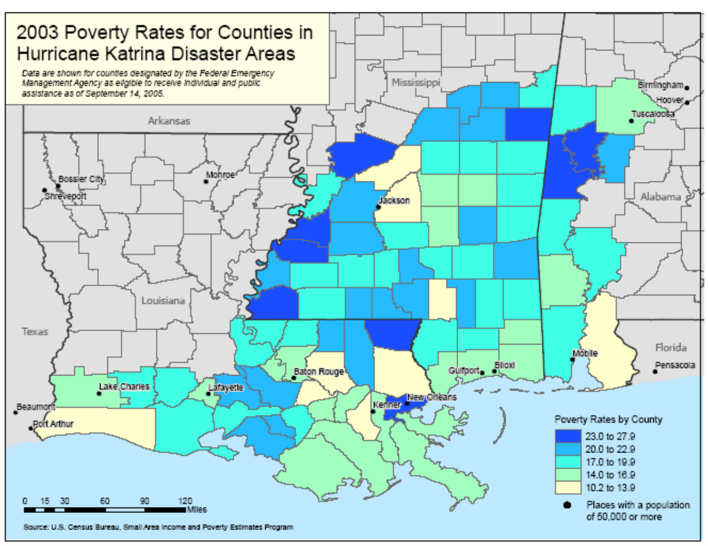

Figure 1: 2003 U.S. Census Map of Poverty Rates

5.2 Housing in the Gulf Coast

For this project we focused on single-family, detached housing, primarily in the poorer areas of the Gulf Coast, both urban and rural. We also looked at some of the conditions specific to New Orleans. There are a number of prevalent housing types present in the Gulf Coast region. Common houses, especially in New Orleans, include shotgun and colonial styles, mostly fashioned out of wood frames with wood siding on narrow lots (Bernhard and Bernhard). It is uncommon for older houses to have insulation within the walls or ceiling. Many houses are built either on grade or raised on a short crawlspace.

Figure 2: Shotgun House, New Orleans

Figure 3: Creole Cottage, New Orleans

5.3 The Hurricane Events

Hurricane Katrina made landfall on August 29, 2005 as a Category 3 hurricane after weakening from a Category 5 hurricane over the Gulf Coast. It was the sixth strongest Atlantic hurricane ever recorded, and it was the costliest hurricane to ever hit the United States, resulting in over $100 billion worth of damage (NCDC; Knabb, Rhome and Brown).

Less than one month later, on September 24, 2005, Hurricane Rita made landfall on the coast of Louisiana and Texas and caused even further catastrophic damage. Rita also began as a Category 5 storm over the Gulf of Mexico and made landfall as a Category 3 storm.

Collectively, both hurricanes resulted in over 1400 deaths and $108 billion in damages. Much of the damage was the result not only of high winds of over 100 mph but of inland flooding, especially in New Orleans, which is 6 feet below sea level on average (Zarrella et al.).

Figure 4: Flooding in New Orleans

Figure 5: Image of Wind Damage in Slidell, LA

5.4 American Diaspora

As a result of Hurricanes Katrina and Rita, hundreds of thousands of people were scattered to all areas of the country during evacuation of the hurricane hit areas. In January, 2006, a study conducted by Brown University (Dao) concluded that as much as 80% of the black population of New Orleans might not return, and the New York Times reported in March of 2006 that up to 50% of the white population might not return (Schwartz). About 40% of the evacuees would most likely return to New Orleans, whereas another 25% would definitely not be returning (Dewan). Most evacuees were reported not to have a new permanent home. By mid-2006, with the next hurricane season only four months away, the levees have not yet been fully repaired, and many former residents are waiting to see how the city and region fare before making the decision to return.

5.5 Who Decides?

After an event with such a large impact, there are a number of parties heavily involved with the rebuilding effort. In our work we have tried to keep ourselves aware of the current effort and the involvement of the parties below. (Contact information is included in Appendix A).

5.5.1 Federal Emergency Management Agency

The Federal Emergency Management Agency (FEMA) is responsible for the administration of the National Flood Insurance Program that has paid out over $526 million by April 2006 to compensate those whose homes were damaged during hurricanes Katrina and Rita. FEMA is also responsible for issuing housing assistance, of which over $209 million have been paid since the hurricane events. FEMA administers a number of other programs to help homeowners, business owners, and the unemployed through funding, house inspections and other programs (FEMA).

FEMA also ensures that the various National Flood Insurance Programs (NFIPs) enforce compliance with floodplain management regulations. The federal government provides flood insurance to those communities that adopt these flood management programs. Under NFIP, a “structure is substantially damaged when the cost of restoring the structure to its previous condition would equal or exceed 50 percent of the market value of the structure before the damage occurred” (NFIP).

5.5.2 U.S. Army Corps of Engineers

The Army Corps of Engineers is working to clear debris from over 2,000 residential properties in addition to working on the redesign and cost estimation of the levees in New Orleans (USACE). The levees are not expected to be able to provide 100-year-flood protection until 2008 according to current plans.

5.5.3 Federation of American Scientists

The Federation of American Scientists (FAS) was formed in 1945 by atomic scientists from the Manhattan Project to promote the humanitarian uses of science and technology. FAS is investigating the use of new materials and design technologies to build quality, energy efficient, affordable, and durable housing in response to disasters such as the Gulf Coast hurricanes. FAS is working on building multiple demonstration houses using a panelized technology called “ThermaSAVE”, both with Habitat for Humanity and independently (FAS).

5.5.4 U.S. Department of Housing and Urban Development

The U.S. Department of Housing and Urban Development (HUD) announced in early 2006 a plan to make HUD properties available to hurricane evacuees for a discount, as well as sponsoring new and re-development along the Gulf Coast in an effort to improve housing, infrastructure and jobs. Additionally, HUD has been working on the design and construction of Transitional Communities, where the infrastructure put in place to support emergency trailers would be transitioned into support for a community of affordable housing (HUD).

5.5.5 Habitat for Humanity

Habitat For Humanity (HFH) has been working on Operation Home Delivery, with the mission to rebuild the Gulf Coast areas affected by hurricanes Katrina and Rita. Habitat affiliates in other areas of the country are working to “pre-build” houses that will be assembled on site in the Gulf Coast (HFH). No set number of houses to be built has been determined.

5.6 What's Happening Now?

As survivors dig the city out of the rubble, FEMA has been working to establish the criteria by which the public will have to rebuild if they intend to meet federal requirements. On April 14, 2006, the New York Times reported that a 3' height off the ground would be required in rebuilding and renovations (Schwartz). The federal government has been criticized for what some call a very lenient ruling though federal official quote that an average house will have to spend $60,000 to be raised to the 3' height (Schwartz). It was expected that the 3' height would be much higher, but federal officials have said that this low requirement is in response to their conclusion that the 1984 flood maps are still fairly accurate – while there has been some subsidence of land, there have also been improvements in mechanical drainage systems (Schwartz).

Concurrent to the 3' rise in houses is a building inspection process, also conducted through FEMA, that dictates whether residents can rebuild an existing house. If the house is less than 50% damaged according to the inspector, the house can be rebuilt. If not, often the owner will head to City Hall to file an appeal (Nossiter). By February of 2006, over 6,000 appeals had been issued. As a result, houses are being rebuilt in areas that are counter to earlier master plans and restrictions on construction quality are becoming more difficult to enforce (Nossiter).

Reports from the Home Depot in Baton Rouge communicate that customers are purchasing a wide variety of products from lumber to appliances and especially an increase in purchases of moisture/mold resistant sheet rock for walls, and treated wood. Customers are also buying the more commonly purchased materials - insulation, from fiberglass to cellulose, to spray in insulation. Some customers are paying a little bit more to get materials of higher durability such as 30-yr wood.

Other organizations are also taking part in the hope to green the reconstruction effort in New Orleans and elsewhere around the Gulf Coast. We spoke with Paul Baricos at the New Orleans Housing Resource Center who discussed current efforts with us including a symposium being held to discuss green and sustainable building, and simply the fact that many citizens of the New Orleans are waiting to rebuild until the federal money is in place and they can be more sure of what they can afford. There has additionally been much confusion as to who was previously required to have flood insurance by FEMA and who was not. Many residents who were told that the federal government did not require them to have the insurance were still flooded during this event.

6 Materials Study

6.1 Materials

We chose to study ten different types of materials for this part of the study. In confining ourselves to the structure and skin of the building, we are neglecting all interior finish materials except drywall, partly for lack of time in this study, but also because interior finish materials will most likely not be the highest priority in housing after the hurricane. Within the structure and skin of the building, we investigated framing, cladding, drainage, insulation, concrete, roofing, structural insulated panels (SIPS), insulated concrete forms (ICFs), drywall and sheathing. Each of these materials either plays an important role in the construction of a well insulated, well drained wall, or serves to substitute other materials (such as the panel and ICF construction possibilities). Within each of these categories, we chose sample materials that are the most easily available in the Gulf Coast area, primarily looking at Home Depot, Lowe's and other sources to ensure that all materials we analyzed are available to our target audience.

6.2 Analysis Criteria

Our study began from an intention to investigate the sustainability of materials that may be used in the reconstruction of the Gulf Coast after hurricanes Katrina and Rita. In this light, we chose categories of criteria for analysis to address the topics that we saw as the most relevant to sustainability in this situation: cost, health, safety, green and local appropriateness.

6.2.1 Cost

In this study we are focusing on the lower income communities of the Gulf Coast, as these were the hardest hit by the hurricanes and are located in the most vulnerable areas to future hurricane damage. As such, the cost of any building assemblies and materials that we propose is of great concern and will no doubt be a large priority to the audience that we are attempting to address.

6.2.2 Health

This category is meant to address the health concerns that may arise from both the manufacture and use of a material. Items of concern here include volatile organic compounds (VOCs) and other harmful byproducts of manufacture.

6.2.3 Safety

This category questions the safety of workers on site when using the given material.

6.2.4 Green

This category addresses more traditional ideas of what makes a material green, including the distance of transport from the location of manufacture, emissions, renewability, and recycled content.

6.2.5 Local Appropriateness

This final category is meant to address the need to pay attention to both the vernacular architecture of the region, as well as user acceptance of new materials and designs. This category begins to investigate the concerns of termites and humidity, which we look into in further detail in the building details study.

6.3 Sources of Information

As the underlying principle of this project is that the majority of information needed by consumers already exists but is simply not accessible to the homeowners, particularly when they are pressed for time and have limited research resources, we have strived to gather readily available information. The majority of the information that we gathered to support our materials study was derived from company product websites, Material Safety Data Sheets (MSDS) (usually from product websites), the Partnership for Advancing Technology in Housing (PATH) building materials database, Environmental Building News, and other scattered sources, including our own experience. Any conclusions we draw about specific materials must carry the disclaimer that this is a preliminary study, based on one semester by a team of students, and though we feel comfortable with all the results presented, this has not been an exhaustive material study, and all our recommendations and findings need to be evaluated further before specific applications.

6.4 Design of the Product Evaluation Sheets

Our intended final product for this study is a user-friendly matrix that a consumer could quickly look at to gather the information that he or she needs to convert their priorities into building material purchase decisions. A consumer particularly interested in concerns about health may have different priorities than one motivated primarily by cost. The final matrix is intended to allow both of these consumers to rank products based on their own priorities and concurrently understand the implications of their decisions in other categories of analysis.

We felt that the matrix had to be as user-friendly as possible so that it may be used quickly and with minimal background information. We therefore chose to follow a similar format to that used by Consumer Reports, where red indicates a better than average result and black indicates one that is less than average. The symbols used were also carefully chosen to be legible even if the matrix is printed in black and white. No two symbols of different rank are the same shape. In addition, we provide two layers of matrices. The first is a detailed matrix in each category. The second is a summary matrix showing all materials studied, evaluated by their performance in each of the five overall evaluation criteria categories.

6.5 Results

Through our research during the materials study, we uncovered a number of trends that overlie the detailed information and convey some important statements regarding material use in reconstruction in the Gulf Coast. We found that, overall, materials touted as mold or moisture resistant all held disclaimers that this did not hold true during ponding or flood conditions. Our conversation with Home Depot revealed that mold and moisture resistant sheetrock product were selling very well. We can draw two conclusions from this - one is that the public is not properly educated about the extents to which their materials can handle their conditions, or that they, like the federal government, consider Katrina to be a one-time event rather than one in a chain. We can also conclude that when other storms hit this area, many of the same impacts will be felt in the future that were experienced during this year.

We also found, not surprisingly, that there were a number of materials that were extremely attractive for a number of reasons including durability, cost, and safety, but conflicted with the more traditional definition of sustainability. An example of this is aluminum siding. Though it is a cheap, durable and an easily used product, it is known to be very high in embodied energy. In this report we provide the information and allow the user to prioritize the various criteria for themselves, but noted this conflict occurs often between sustainability, durability and cost.

Finally, we found a number of materials that fell into a range of levels of performance rather than a discrete point. One example of this is EIFS. EIFS can be interpreted in a number of ways – from cheaper to more expensive, all levels of which carry with them a large variety in performance from durability to ease of use to energy efficiency potential and moisture implications. Many of these materials are more impacted by the building detail that is used for their assembly than by the background of the material category itself.

Figure 6. Product Evaluation Sheets

Summary

	HEALTH	SAFETY	COST	LOCAL	GREEN
Drainage					
Fortifiber Building Systems Group ®	□	□	□	□	x
15# Felt Paper, Asfelt	⊠		□	□	
DuPont™ Tyvek® HomeWrap®	□		⊠	□	?
BBA Fiberweb™, Typar HouseWrap	□	▣	□	x	□
Insulated Concrete Forms					
Quad-lock® Quad-lock for Walls	□	▣	⊠	□	⊠
Polysteel PS•4000 Flat Wall Form	□	▣	⊠	□	⊠
Styrofoam T-Mass Technology	□	▣	⊠	▣	⊠
Siding					
Hardiplank ® Lap Siding	⊠	▣	□	▣	▣
Cypress Siding	□	□	⊠	⊠	□
Vinyl Siding	⊠	□	□	□	⊠
Aluminum Siding	□	□	□	□	▣
Stucco	□	⊠	□	□	▣
EIFS	□	⊠	⊠	⊠	x
Roofing					
Asphalt Shinglesm XT-30 Impact Resistant	□	⊠	⊠	□	⊠
SBS-modified asphalt shingles, StormMaster LM	□	⊠	⊠	□	⊠
Metal roof panel, ScanRoof®	□	□	□	⊠	▣
Standing Seam metal, MasterLok-90	□	▣	□	⊠	▣
Tital Cool Roof Coatings, TITAN Cool Roof	□	□	?		□
Gypsum Board					
DensArmor®	□	□	□	▣	□
ToughRock®	□	▣	□	□	□
FIBEROCK® AQUA-TOUGH™	□	■	□	▣	▣
Hardibacker®	□	■	□	▣	□
Sheathing					
DensGlass Gold ®	□	□		□	□
OSB	□	□	□	□	▣
Plywood	□	□	⊠	□	▣

	HEALTH	SAFETY	COST	LOCAL	GREEN
Insulation					
ProPink®	□	?	□	□	□
Foamular®	□	▣	▣	□	□
Guardian Fiberglass	□	?	□	?	□
ComfortTherm	▣	□	□	□	□
MR Faced Batts	□	□	?	□	□
Climate Pro®	▣	□	⊠	□	□
Cocoon® Insulation	□	□	⊠	⊠	▣
The Icynene Insulation System®	?	▣	⊠	▣	□
Cotton Insulation	■	?	□	?	▣
Dow Styrofoam® Blue Board	⊠	▣	?	□	?
Studs					
Southern Pine	□	□	□	□	▣
Machine Stress Rated	□	▣	□	□	▣
Western Douglas Fir	□	▣	□	□	□
Pressure treated wood	⊠	▣	□	▣	□
Metal	□		⊠	■	▣
Panel Construction					
ThermaSAVE, ThermaSAVE Building Systems	⊠		□		□
General Panels, General Panel	⊠	□	□	□	
R-Control SIP, R-Control Building Systems	⊠	□	□	□	
Thermocore™ SIP, Thermocore™ Panel Systems	□	□	⊠	□	
Concrete & Masonry					
Concrete traditional	□	□	□	□	□
Concrete with fly ash	□	▣	□	⊠	▣
Brick	□	□	□	□	□
Cinder Blocks / CMU	□	□	▣	⊠	□
AAC Concrete	□	□	□	⊠	□
Concrete with ductal	□	▣	□	⊠	□

LEGEND	
■	Excellent
▣	Above Average
□	Standard
⊠	Below Average
x	Poor
$	Low to Average Cost
$$	High to Average Cost
?	Inconclusive Information
(Blank)	Undetermined

7 Testing

Two types of tests were conducted on two different types of wall panels: load tests and assembly tests. The panels tested were of two types, 4" expanded polystyrene foam core with either the fiber cement board sandwich from ThermaSAVE, or a similar panel with Oriented Strand Board (OSB) as the outer layers, both manufactured by the same party.

7.1 Assembly Tests

As we were previously unacquainted with the ThermaSAVE panel system, we took the opportunity to examine some of the basic structural properties and applications of the panel technology to try to understand what advantages and disadvantages the use of this technology may hold for the new user attempting to build efficient, durable, quick housing in the Gulf Coast reconstruction effort. We elected to examine the panels in four ways: general observation, assembly, conduit routing test, and a water joint test.

7.1.1 General Observations

We received four ThermaSAVE panels and four OSB panels, all measuring 2' x 2' square. The panels were donated by Hoot Haddock of ThermaSAVE, who also provided the OSB and fiber-cement splines and screws for connecting both types of panels. The panels were virgin panels (not scrap) and were packaged by a third party and shipped from Alabama to Berkeley, CA.

When we received the panels, we documented the condition of each with photographs and written descriptions (Appendix E). In general, the ThermaSAVE panels were not in optimal condition. The delivery process resulted in a number of cracks and dents of the fiber-cement skin. The OSB SIPs fared much better, only exhibiting a couple of damaged OSB corners.

7.1.2 Assembly

We chose the best two panels of each type and joined them together following our basic understanding of the details provided on the ThermaSAVE website. Joining both the ThermaSAVE SIPs and the OSB SIPs was a very similar process. We used OSB splines for both panel types as we were not aware that our delivery also contained fiber-cement splines. With both panel types, we experienced the same difficulties of the spline routs being sized awkwardly such that it was difficult to square the total assembly and make both panels flush to each other (see following Figures).

Figure 7: ThermaSAVE SIP Assembly

Figure 8: OSB SIP Assembly

This study provided further questions about how the application of ThermaSAVE technology may succeed in the field including:

- If people do use OSB splines to join the ThermaSAVE panels, would the differing rates of expansion and contraction between the OSB and the fiber-cement skin cause durability problems?

- Does the powdery nature of the fiber cement skin provide a sufficient bearing surface for the screws to hold the structure together over the long-term?

- Does the weight of the ThermaSAVE panel (approximately 176 pounds for a 4'x8' ThermaSAVE panel vs. 104 pounds for a 4'x8' OSB SIP) create a need for additional labor or equipment on site that would not be necessary for a structure built out of OSB SIPs?

7.1.3 Conduit Test

Both the ThermaSAVE panels and the OSB SIP panels are typically manufactured with part of the interstitial foam routed out to provide a space for running electrical wiring. It is often noted by SIPs users that it is sometimes difficult to line up these conduit runs in the field while assembling panels. Also, some codes require that the channels be greater than 1.25 inches from the nailing surface. One of the ways we have heard of people dealing with this is to rout the necessary channel through the surface of the panel, thus compromising the structural integrity of the SIP system. (Note that this is not an approved means of treating the panels). We were curious as to how the two different types of panels might react to this possible field condition and so recreated the condition in one panel of each type and applied pressure to the side of the panel opposite the rigged rout. The OSB SIP broke after 6 sturdy jumps on the cantilevered side, while the ThermaSAVE panel snapped in two with only the slightest pressure. The question remains which condition would be more desirable in a house – a compromised panel that was still intact (such as the OSB SIP), or a panel that was legibly compromised (such as ThermaSAVE).

Figure 9: Conduit Test, OSB SIP

Figure 10: Conduit Test, ThermaSAVE SIP

7.1.4 Water Testing the Panel Joints

Finally, we were curious as to the possible transmittance of water through the assembled joint of each panel type as well as the ability of ThermaSAVE to act alone without an exterior drainage plane or cladding. We applied water from a hose normal to the assembled joint (without caulk or sealant) of each panel type from a distance of approximately 4 feet for one minute. Neither panel exhibited any water transfer from one side of the joint to the other in this test. Further tests may be necessary to determine the effect of continuous driving rain on the assembly detail of each panel type.

Figure 11: OSB SIP Joint Water Test

Figure 12: ThermaSAVE SIP Joint Water Test

7.2 Diagonal Load Tests

The purpose of the load test was to determine how the strengths of the competing panels varied when they were exposed to humidity or bulk moisture. We obtained six total panels: three ThermaSAVE and three OSB SIPs.

Each panel was 4.5 inches thick (0.5 inch OSB or fiber cement on either side with a 3.5 inch EPS core) and 3 feet square.

7.2.1 Panel Preparation

We placed one panel of each type into a moisture chamber set at 95% relative humidity for five weeks, simulating humid weather conditions, which we called the "moist" setting. In the same moisture chamber room, we immersed a pair of standing panels approximately 1.5 feet deep in standing water, which we called the "wet" setting[1]. The third pair of panels was left "dry," outside of the moisture chamber room.

Figure 13. OSB SIPS: Dry, Moist, and Wet Panels

[1] Initially, we planned to immerse the "wet" panels completely under water in one larger pool with the panels resting flat on the ground. In setting this up, we found that the panels float and had to add weight to keep them submerged. Within one day, this pool had lost all of its water due to a leak. We revised our strategy, obtaining a new, smaller pool and set the panels up as discussed above. In truth, this latter setup more approximates what a wall may experience during flooding – where the lower part of the wall is submerged and the upper part is only exposed to humidity. In total, the "wet" panels were soaked completely for 1 day, moistened for 3 days, and then soaked partially in the moisture room for 31 days. The other two "humidified" panels were in the chamber for a total of 35 days. At the end of this time, these 4 panels as well as the two dry panels were setup for the diagonal shear test.

Figure 14. ThermaSAVE Panels: Dry, Moist, and Wet Panels

For the testing process, we first prepared each of the three OSB specimens. We inspected each panel and recorded our observations. We chose the most similar and square set of opposite corners as the corners to be loaded in the testing process. We placed the two opposite loaded corners into steel loading shoes (see photos) and kept them in place with hydrostone. The hydrostone served as a filler and bonder between the panel corner and the steel shoe. The purpose of the steel shoe was to help distribute applied load throughout the panel. We installed two pairs of gauges, one attached horizontally between bolts at the corners of the panel, and one pair attached vertically between the loading shoes, on each side of the panel. We set one pair of gauges to measure deflection vertically, in the direction of the load, and the other horizontally.

Figure 15. OSB SIP Dry Panel Preparation

In Figure 15, a pair of gauges, not shown, connected along the horizontal line measures elongation along that line due to shearing, as the panel is being loaded; the vertical gauges, one of which is shown, measure vertical shortening.

Each of the ThermaSAVE panels that we received was damaged in transport such that no panel had two opposite undamaged corners that could accommodate the loading shoes. We dealt with this by cutting the panels down to 2 feet square. Though this meant that the OSB SIPs and ThermaSAVE panels tested were different sizes, it did allow us to obtain better data for comparison between the ThermaSAVE panels. We still compare data to the 3 foot square OSB panels with this in mind. After cutting the panels down, we followed the same panel preparation procedure as that for the OSB SIPs.

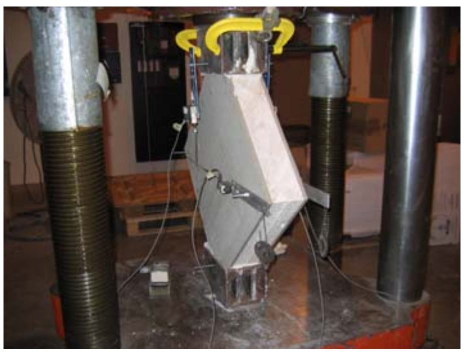

Figure 16. ThermSAVE panel (dry) loaded in testing machine

Load, time, horizontal and vertical displacement data were recorded for each test. From these data, we calculated the percentage drift and plotted it against the load. Drift is an approximation of the panel's shear deformation and is defined by the equation

$$\delta = \frac{L - \sqrt{\left(\sqrt{2}L - \Delta_u\right)^2 - L^2}}{L}$$

where:

L = length of the shear plane, or the diagonal line from corner to corner (This length was 51 and 34 inches for the OSB and ThermaSAVE panels respectively), and

δ = average of the magnitude change in length of each vertical gauge. We calculated this by taking the average of the absolute values of the two measurements made by the dual vertical gauges. The load versus drift plots are shown in Appendix D.

ThermaSAVE panels yielded at loads which are 2 to 4 times greater than the yield points for the comparable OSB panels. There is, however, no coherent comparison of panel strength under increased moisture conditions. The yield point of the dry OSB panel is around 9 kips and drops by 40% to 6 kips for both the moist and wet panels. For ThermaSAVE, the yielding load *increases* 20% from 21 kips for the dry panel to 26 kips for the moist specimen, and then decreases to 15 kips for the wet specimen.

It seems reasonable to assume that moisture and saturation decrease strength in the OSB panels by separating bonds within the material. One possible explanation for ThermaSAVE is that the water in the moist panel reacted with cement material, producing hydration products which increased its strength. Too much water however, as in the wet condition, decreased bonding within the material, which was obvious by lamination of the corners of the ThermaSAVE panels.

We also noted the conditions of the panels before and during testing, as shown in Figure 13 and Figure 14. The dry OSB and Thermasave panels did not look any different than their initial conditions, five weeks prior to testing. All moist and wet OSB and the wet ThermaSAVE panels developed brown, black, blue, green, and white molds on their edges and faces. The mold on the ThermaSAVE panels could be easily wiped off, unlike the mold on the OSB. The moist and wet OSB SIPs also exhibited expansion of the OSB sheathing and were soft to the touch.

All of the panels failed in a similar manner during testing by the development of a crack in the panel corner along the edge of the top steel shoe. Corner cracks in the OSB panels, however, were much more jagged, while cracking in ThermaSAVE was more linear and clean-cut with occasional delamination between the fiber cement and the EPS core near the loading point. The moist and wet OSB SIPs produced less of a defined crack and more of a brooming effect where the OSB fibers were simply crushed.

Figure 17. OSB SIP Failure Points: Dry, Moist, and Wet

Figure 18. ThermaSAVE Failure Points: Dry, Moist, and Wet

It is also worth noting that the ThermaSAVE panels released a considerable amount of dust while being cut (Figure 19).

Figure 19. Cutting ThermaSAVE panels

In summary, the ThermaSAVE panels exhibited a much higher shear strength than the OSB panels under the dry, moist, and wet condition simulations. ThermaSAVE's strength increased for the moist condition, although one test is inadequate for drawing definitive conclusions. Both types of panels developed mold when exposed to moisture and all panels failed by crack propagation around the corners when shear forces were applied.

8 Building Codes and Details

8.1 Building Codes

Poor construction quality can result in serious damage to homes from hurricanes and flooding. In 1989, Hurricane Hugo caused more damage than any other North American hurricane in history, including extensive damage to residences (Comerio). In the *Journal of Coastal Research*, Peter Sparks explains how winds can cause major structural damage:

> "As wind flows around a building it includes positive (inward) pressures on the windward face and negative (outward) pressures on the leeward face. The side walls are generally subjected to negative pressures which can be very intense near the windward corners of the building. A similar situation occurs with flat roofs and on gable roofs when the wind is blowing parallel to the roof edge....The creation of an opening in a windward wall creates a positive internal pressure in producing an uplift on the roof.
>
> "The intense negative pressures occur over quite small areas. Their effects are seen in the removal of roofing materials near the edges of the roofs and the cladding materials near the corners of walls....Major structural damage in often initiated by the loss of the roof structure, precipitated by increased internal pressure due to window damage...A second form of failure [results from wind-induced] bending action [that] can sometimes overturn a structure or separate stories" (Comerio).

According to Mary Comerio, an expert on disaster damage to homes, most of the damage caused by Hurricane Hugo occurred where the hurricane wind conditions had a "recurrence of between 20 and 50 years and was the result of owners, insurers, and government accepting forms of construction with wind resistance less than that recommended by the engineering profession" (Comerio). The result of "minor wind failure," such as losing roofing shingles, hugely increased the "dollar value of damage" to the interior of the homes (Comerio). Several studies estimated that the subsequent rain damage to the interiors of the homes "magnified the initial damage by a factor of ten to thirty times" the damage to the roofs (Comerio).

Hurricane Andrew (1992) also caused heavy residential damage, due to several factors. The South Florida Building Code included several requirements for hurricane-resistant construction, but the actual hurricane winds exceeded the stipulated design wind speed in the code (Comerio). According to Comerio,

> "Hurricane straps, the most obvious preventive measure, were generally installed in an effective manner; however, inspectors found that less obvious details, such as fastener spacing on roof sheathing, which ultimately determines the structural capacity of the roof system, were not in compliance with the codes. Further, the combination of gable roofs, poor quality materials, and unprotected openings led to a high degree of roof and water damage."

The families hit hardest by hurricanes and other natural disasters are often the "poorest populations in the poorest quality homes" (Comerio).

In a conversation with an official at the Building Codes Office in Baton Rouge, we learned that while the state of Louisiana uses the building codes from the International Council of Codes (ICC), each parish (county) is responsible for making their own "amendments" to those codes. Amendments to codes allow communities to enforce necessary regulations that are unique to their area. For example, an area that is especially prone to wildfires may make an amendment to the codes requiring walls systems to have better fire performance. Louisiana has been on '03 codes and is reverting to the newer '06 codes by January of 2007. When asked what hurricane-related amendments the parishes might make, the building codes official anticipated a change in the current wind load standard on buildings of 110 mph to 150 mph. He also expected that new buildings would be required to be elevated above ground level.

In terms of the work load at the building codes office after the devastation in Louisiana, the official expressed regret over the lack of funds which was affecting the performance of building codes inspectors. Inspectors inspect damaged homes to determine if they are not substantially damaged and are allowed to be repaired. Instead of checking 3 houses a day, they are checking 30 houses a day, and don't get enough time to inspect homes properly. When asked if people were building anything differently, he mentioned that some were using metal framing for residential construction rather than wood framing because of its termite resistance and ability to sustain higher wind loads.

8.2 Building Details

Once we substantially completed our analysis of common and possible alternative building materials that may be used in the Gulf Coast area as people rebuild, we continued further with the study by concerning ourselves with the way in which these materials would be assembled into a house. The properties of the materials themselves are crucial in the understanding of the properties of the composite building assembly, but there are added concerns that are addressed only with the total assembly of these materials. We decided to analyze four categories of building details, where we saw the most potential for hurricane related damage: wall to roof connections, wall drainage and insulation, window flashing, and sill connections. Within each category, we chose to analyze details from three different building types: best practice construction, OSB SIPS construction, and ThermaSAVE SIPS construction.

Our goal in this analysis was to assemble a list of advantages and disadvantages of each building detail using the same criteria as that used in the materials study, as well as the additional criteria of understanding how the assembly will fare in the hurricane conditions of wind, rain, flooding and the local issue of termites. For those who may use our work as a beginning reference to assist with decision making and prioritization of building strategies in rebuilding the Gulf Coast, we hope this analysis will teach users that it is not simply what product they choose but also how they use it that will determine the lifetime performance of their buildings.

8.2.1 Three Example Buildings Types

Our intention was not to create new innovative solutions, but rather to use existing building assembly details that are commonly or easily constructed with materials of particular interest and to determine whether they are appropriate for rebuilding in the U.S. Gulf Coast. In general, they all require some level of homeowner and builder education and attention.

In the aftermath of disasters such as Katrina, quick building options present valuable possibilities to house many people quickly. Structural Insulated Panels are sandwiches of expanded polystyrene between two sheets of OSB (oriented strand board). These panels are meant to be substituted for the insulation, structure, and sheathing of a conventional house but still require the same drainage, interior wall finish, and cladding treatments that a conventional house would require. ThermaSAVE substitutes fiber cement board for the OSB of conventional SIPs and thus claims that no cladding is needed and the panels may serve as a substitute for an entire wall from inside to out. We are comparing these two panel systems to better understand what tradeoffs are made for the advantage of quick construction and what one must pay attention to when using these panel assemblies.

8.2.2 Results and Discussion

The four different types of building details that we evaluated (roof-to-wall, wall drainage and insulation, window flashing, and sill details) were the set of details we considered most important for the region, in light of the local climate and pests. The details we examined came from the *Hot-Humid House Plans* proposed by the Building Science Corporation (BSC) in their "Houses That Work" study, the SIP Association website, and the ThermaSAVE website (ThermaSAVE). Within each building detail category, we identify positive and negative aspects of each detail. Lastly, we touch upon how the SIPs and Best Practice details could be translated for use in building with ThermaSAVE as ThermaSAVE's online details are relatively sparse.

ROOF TO WALL: BEST PRACTICE

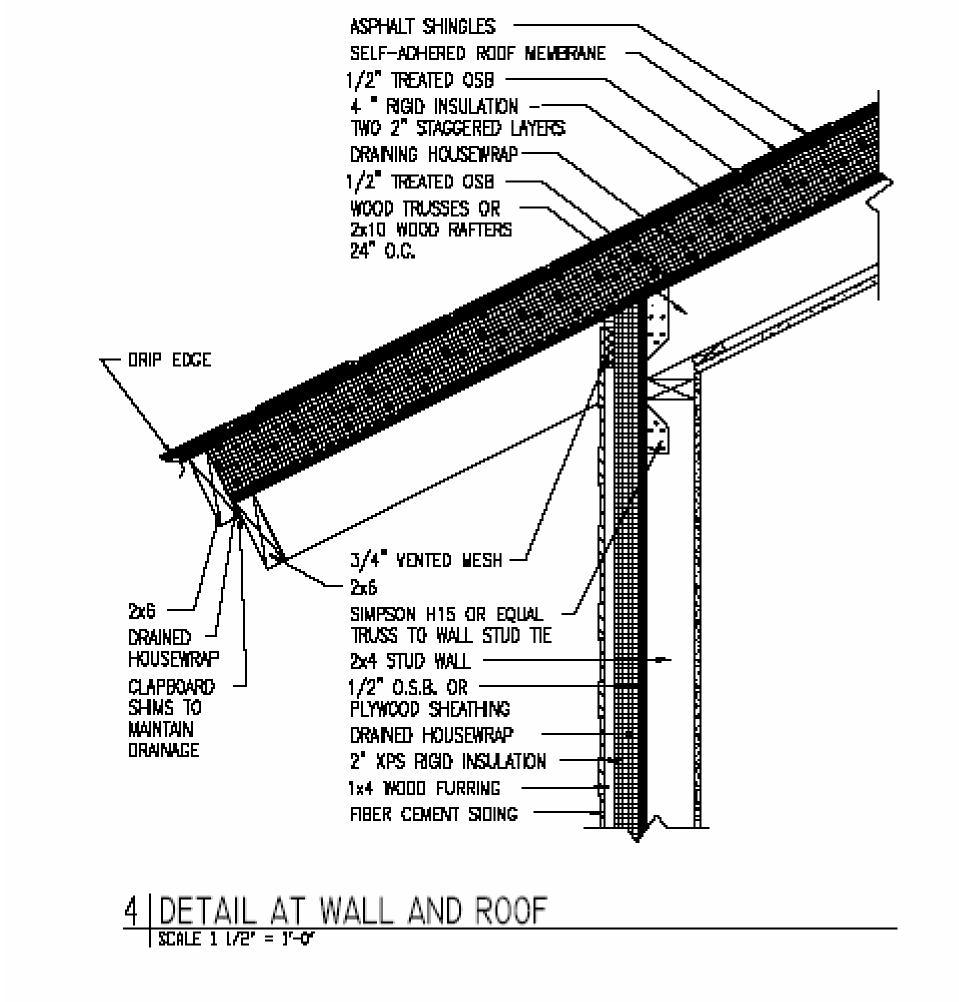

Figure 20: "Best Practice" Roof to Wall Detail, Building Science Corporation

This best practice detail of a wall to roof connection shows a properly moisture-managed system that has the additional benefit of being exceptionally energy efficient and designed for durability. Most of the material components are relatively inexpensive, durable, and their assembly is truly optimal with respect to durability, heat, and moisture. However, when a homeowner or builder considers following this detail as an example, he/she should be aware of a number of things. Firstly, it is common for shingle manufacturers to void their warranty if, as in this detail, the roofline is not vented. For energy purposes, the fact that this roofline is not vented is optimal, and is consistent with the conditions that we will encounter in the OSB SIPS and the ThermaSAVE situations, but research will need to be done to find a product manufacturer that approves of this assembly. The configuration of the drip edge should effectively protect the rafters from moisture damage. Finally, the detail shows a double layers of rigid foam insulation in the middle of the roof assembly. We are unclear as to how this assembly would be fastened together in such a way as to prevent thermal bridging through metal fasteners penetrating the insulation to hold the upper and lower OSB layers together. Additionally, as builders will not see this as standard practice, it may require negotiation and possibly extra cost to follow this detail.

ROOF TO WALL: SIPS

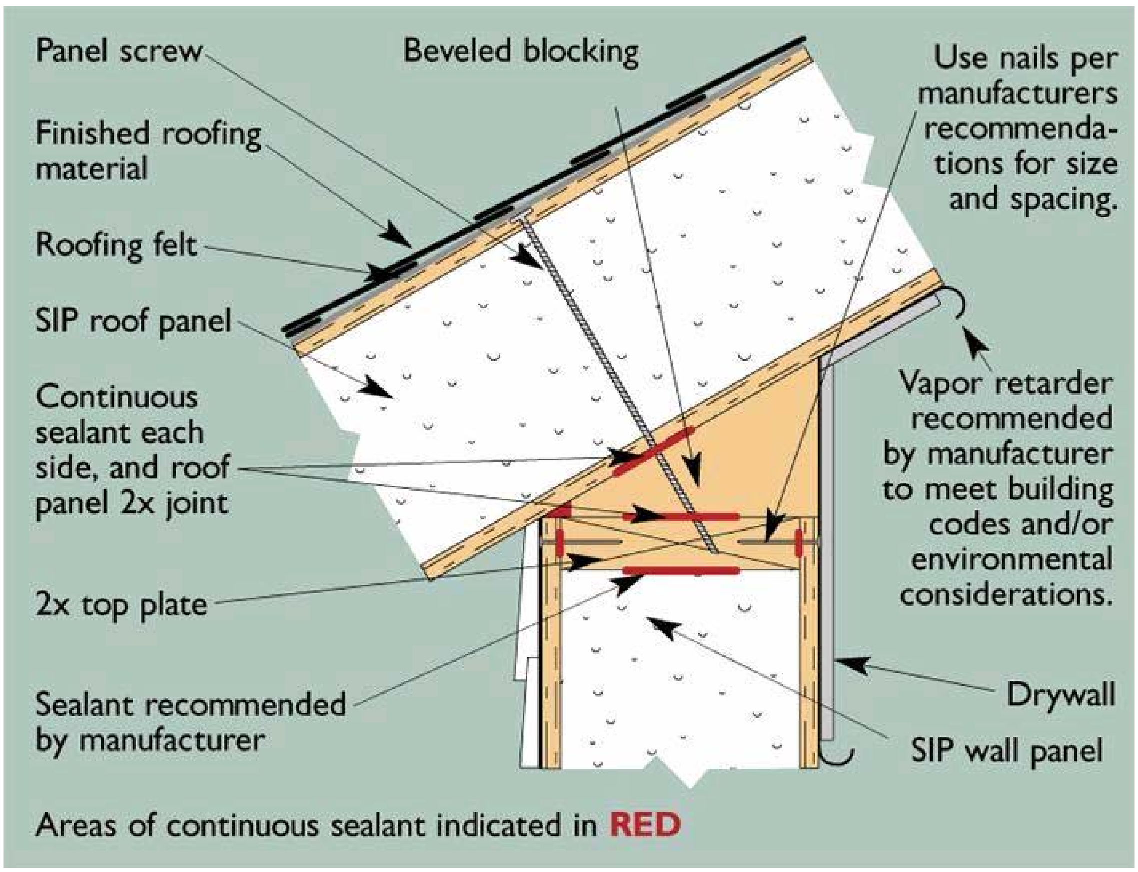

Figure 21: SIP Association Roof to Wall Detail

As previously mentioned, research will be required to locate a shingle manufacturer that will approve of this unvented roof assembly. Though in many other ways, this detail carries many of the benefits experienced in the Best Practice detail. Thermal bridging of rafters has been eliminated, as there are no rafters and generally no though penetrations of the roof insulation. No eave detail is shown, but following the recommendations in the Best Practice detail would be a possibility. Again, there are a number of points that an owner or builder should be aware of when considering the use of this detail. Firstly, the locations marked for sealant are nearly impossible to access. The alternative would be to seal all seams of the joined SIPS assembly and use spray foam insulation to adhere the inlayed 2x material into the panel edges. Additionally, though the detail recommends the placement of a vapor retarder behind the drywall, it is recommended that a high permeability rating be used as a hot-humid climate such as that found in the Gulf Coast will be prone to condensation issues no matter on which side of the wall the vapor barrier is placed.

ROOF TO WALL: THERMASAVE

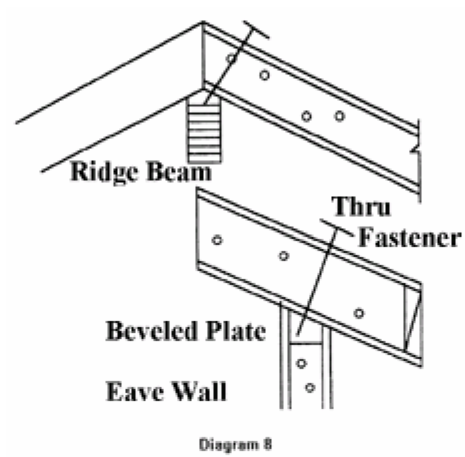

Figure 22: ThermaSAVE SIP Roof to Wall Detail

This detail is inadequate. The user should follow the recommendations found in the OSB SIPS details.

WALL DRAINAGE AND INSULATION: BEST PRACTICE

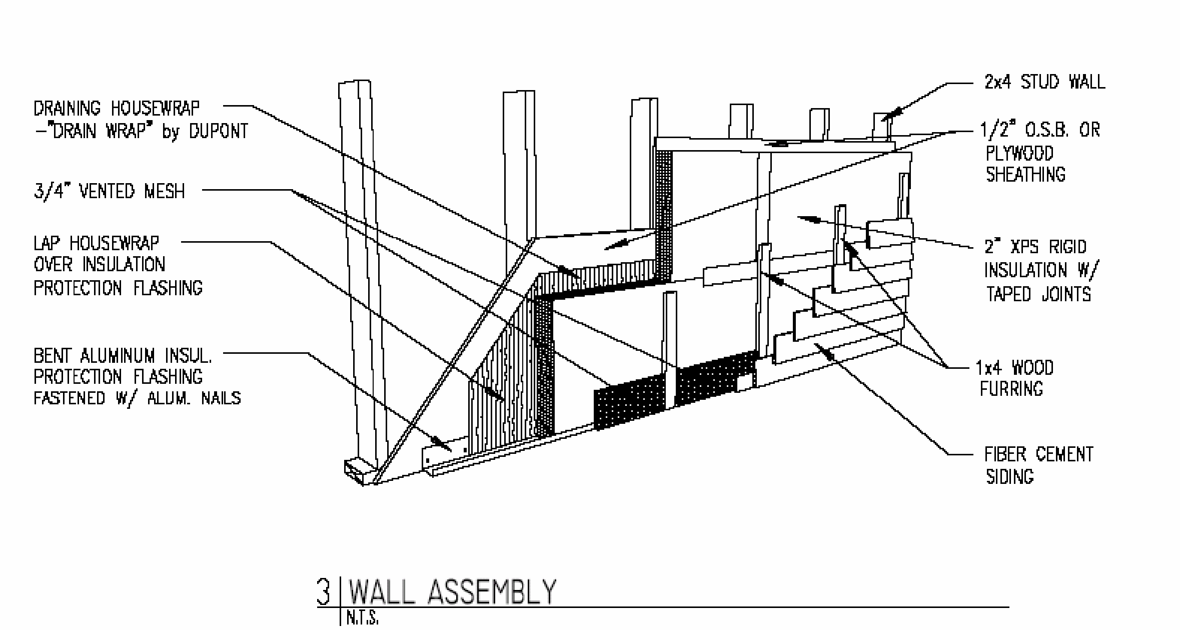

Figure 23: "Best Practice" Wall Drainage and Insulation Detail, Building Science Corporation

As with the Best Practice detail for the roof to wall connection, this detail shows a solid approach to energy efficiency, durability and moisture management but again carries with it some added labor and education of the builder to ensure that it is carried out properly. As shown in the materials study, fiber cement siding is a good option for a relatively low cost, durable cladding option and is at its best in this climate when combined, as shown here, with a proper drainage plane. Additionally this detail again carries the benefit of reducing thermal bridging through the insulation by placing the insulating layer exterior to the studs, though indeed this is not conventional and therefore may require additional education and convincing to see it through.

SURFACE SPLINE CONNECTIONS: SIPS (spline connection and 2 x 4 connection)

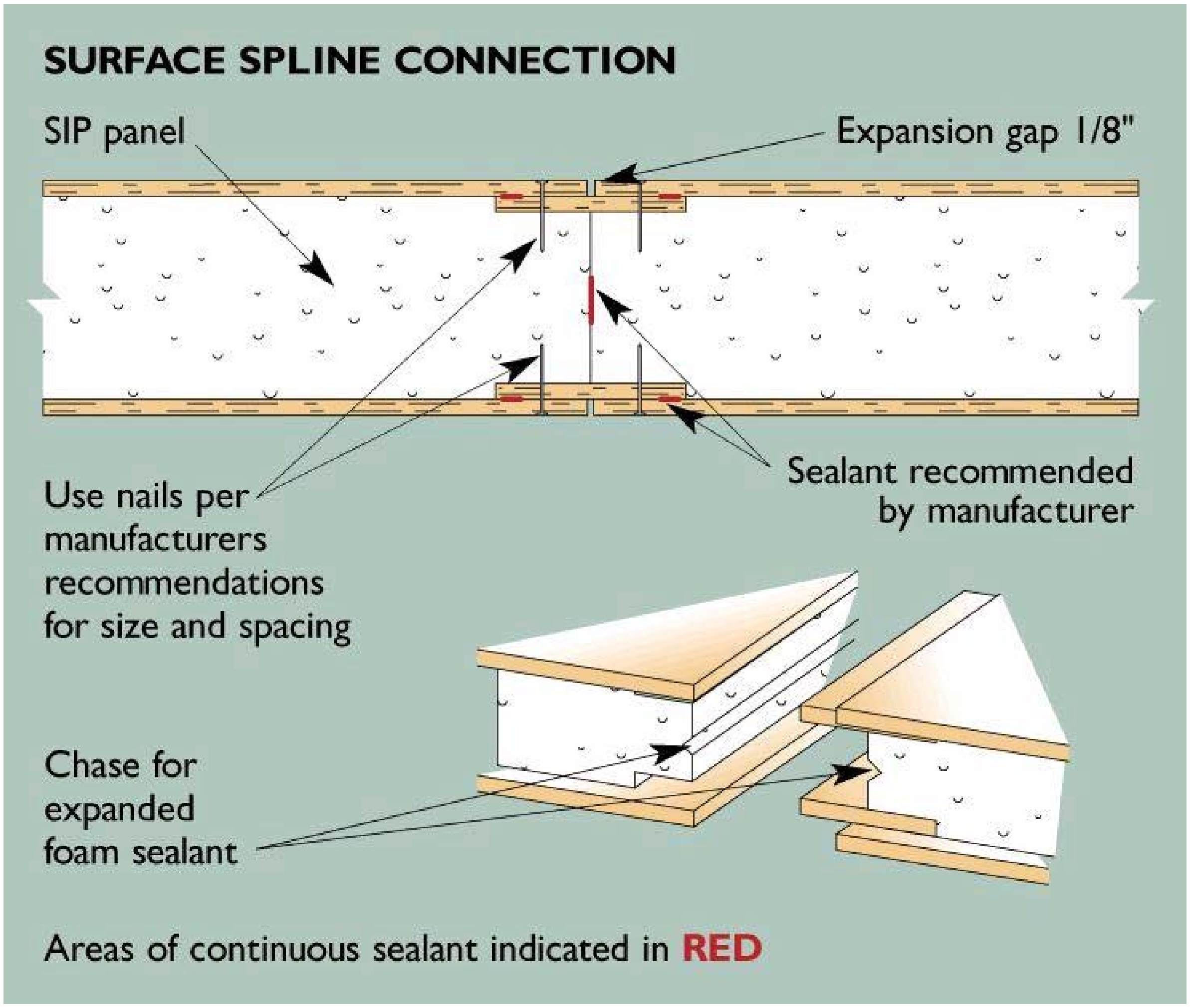

Figure 24: SIP Surface Spline Connection Detail

OSB SIPS do not claim to be able to replace the entire wall assembly. They generally are only meant to substitute for the studs, insulation and sheathing, and thus would require the additional layers as shown in the best practice detail to provide an adequate drainage plane and cladding layers. This detail mostly shows the connection of the panels together. Again, the sealing detail shown is unrealistic – an easier approach that would accomplish the same end would be to spray foam insulation in the groove before inserting the spline, then caulking the final joint after assembly is complete.

WALL DRAINAGE: THERMASAVE

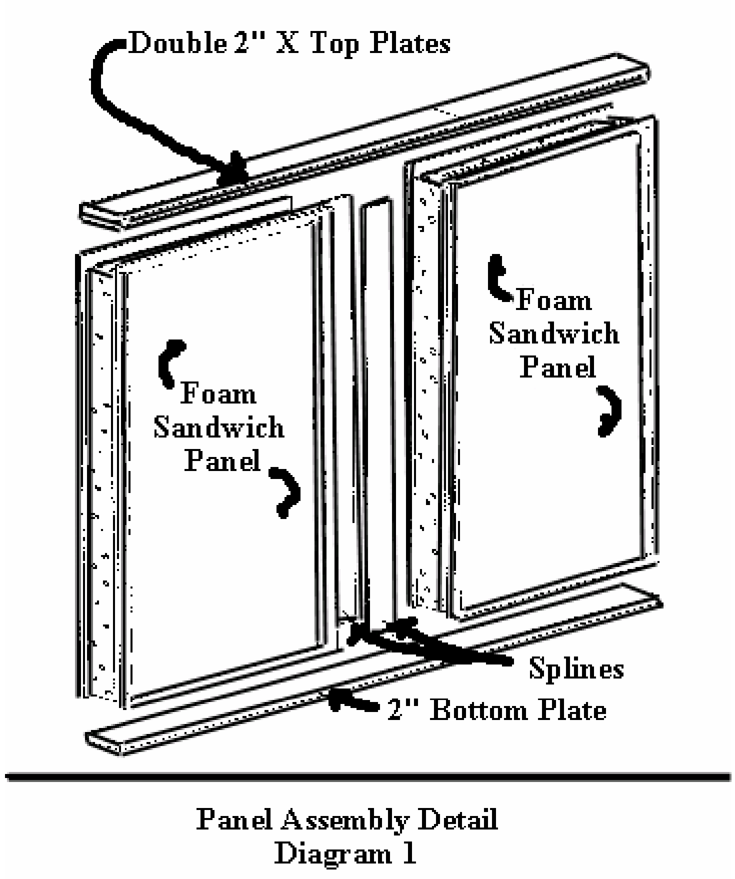

Figure 25: ThermaSAVE SIP Wall Drainage Detail

This detail is inadequate. As mentioned earlier, it is recommended that the user follow the recommendations we make for SIPS and Best Practice details. Additionally, as mentioned earlier as well, we are unsure as to what the intended materials are that will be used for the top plates. If it is indeed wood, then the ThermaSAVE claim that houses can be built entirely without wood is false and attention must be paid both to the potential issues of expansion and contraction of this embedded 2x material as well as to appropriate termite flashing to prevent the decomposition of this important structural member.

WINDOW FLASHING: BEST PRACTICE

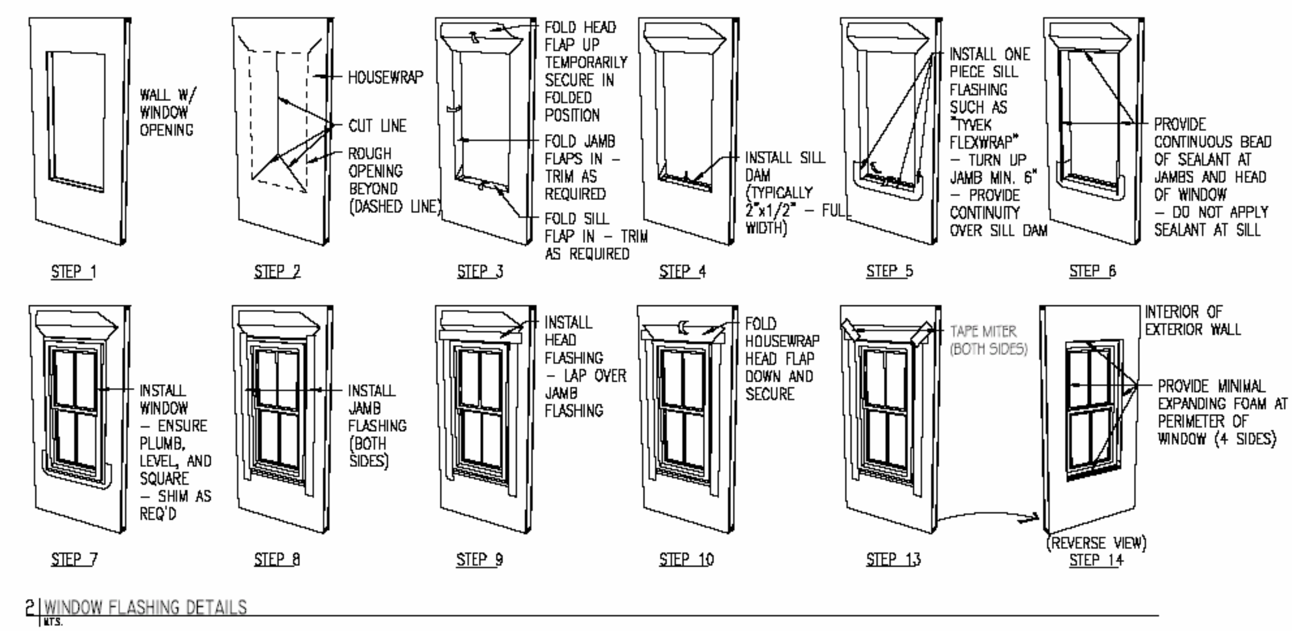

Figure 26: "Best Practice" Window Flashing Detail, Building Science Corporation

The Best Practice detail shown here focuses on how the drainage plane must be cut and placed around the window such that no water will be led into the window frame itself. Though it seems a simple principle, it is often not carried out this way. This is a crucial detail to preventing moisture issues in a house and should not be overlooked though it will require education of the builder, in many cases, to carry out.

WINDOW FLASHING: SIPS, THERMASAVE

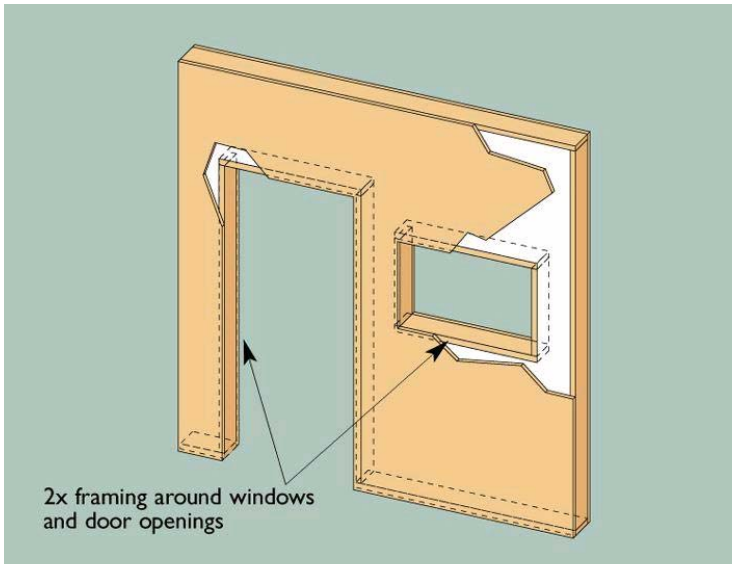

Figure 27: SIP Association Window Flashing Detail

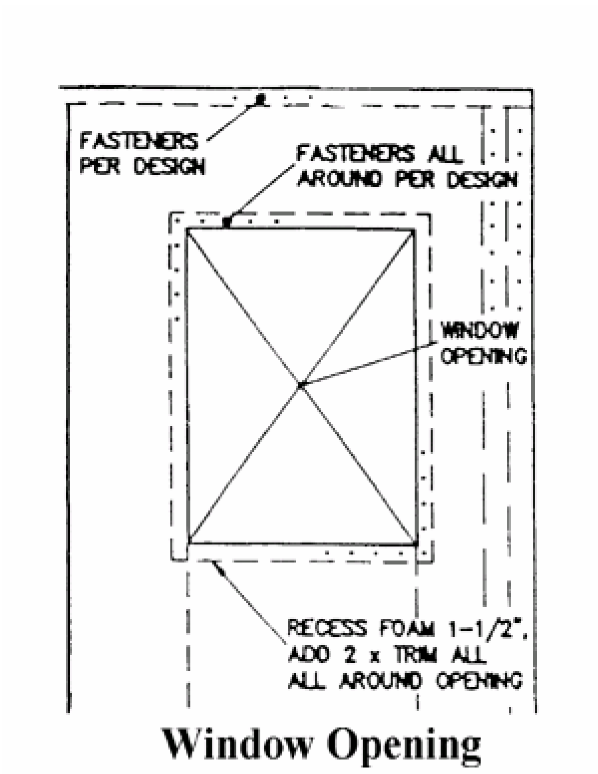

Figure 28: ThermaSAVE SIP Window Flashing Detail

Neither the SIP Association nor ThermaSAVE supply a detail to explain the assembly of the window system beyond simply the attachment of the window to the wall. In the case of OSB SIPS, where the SIP is meant to have drainage and cladding attached to it after assembly, the drainage can be carried out in the same manner as that used in the Best Practice detail. It is unclear, however, how one would keep water out of the window frame in the ThermaSAVE structure where it is not intended to have any additional drainage or cladding layers could be added. We see this as an area that requires further testing and study to understand how best this detail can be arranged.

SILL DETAIL: BEST PRACTICE

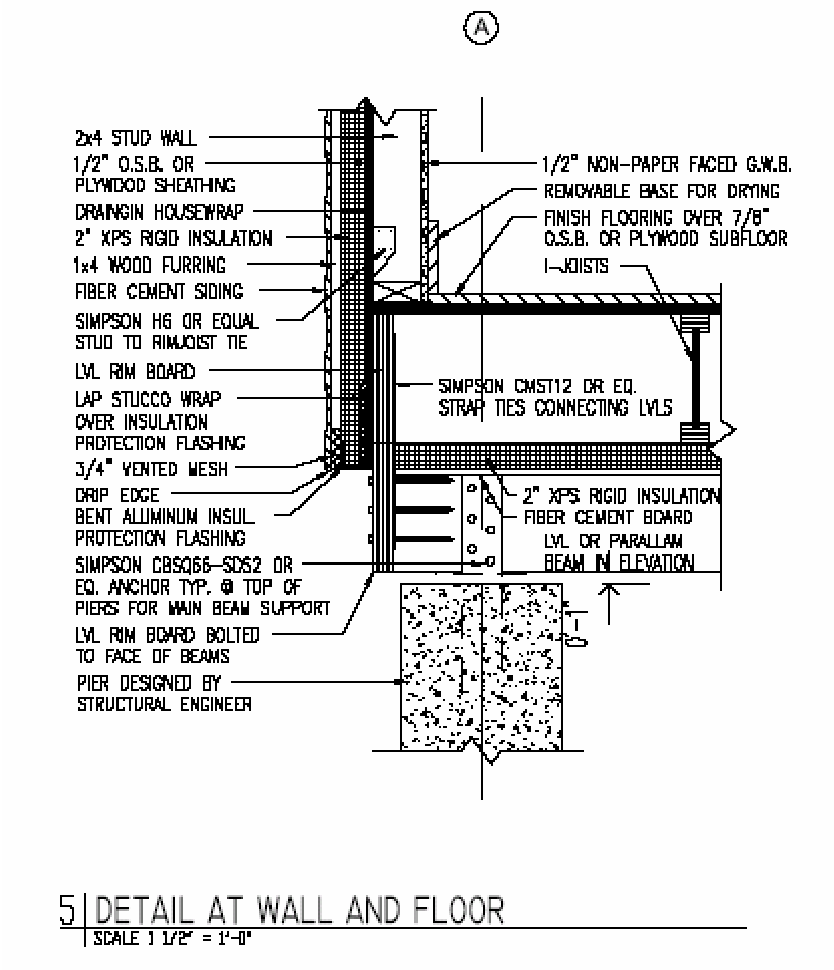

Figure 29: "Best Practice" Sill Detail, Building Science Corporation

Containing many layers, this detail is much more complicated than the conventional sill construction that one is most likely to encounter in the area. The detail effectively handles concerns of strength, durability, moisture management and termite protection, but at the cost of creating a very elaborate, labor intensive construction assembly. Education and possibly extra cost would be associated with carrying out this detail. We remain unsure as to how the I-joists are meant to stand on the insulation. The removable base for interior drying of the wall is probably an effective strategy but will require user education and vigilance. Additionally, the thickened floor will create higher costs in all wall cladding and drainage that will have to cover the additional façade square footage.

SILL DETAILS: SIPS

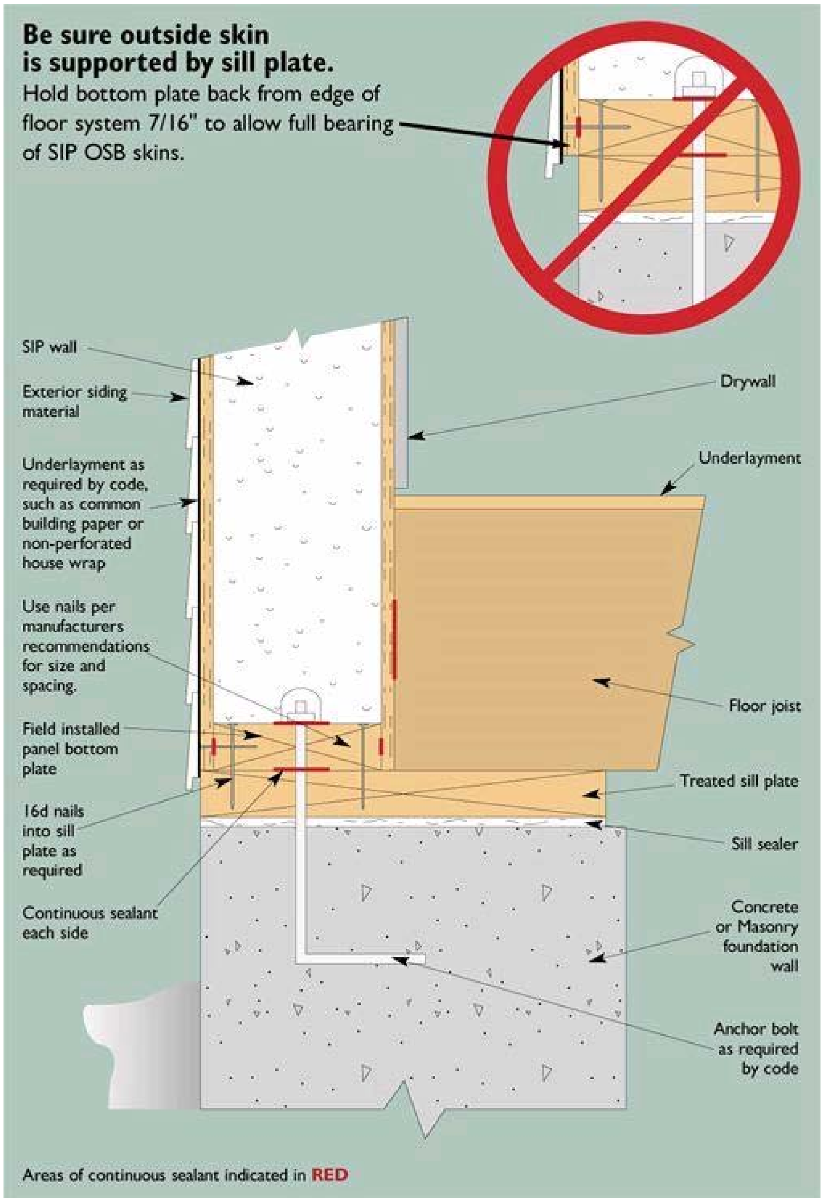

Figure 30: SIP Association Sill Detail

Though much more simple than the Best Practice detail, this assembly is missing the application of termite flashing that will be needed in this region as well as the provision for a proper drainage plane with furring out of the siding as shown in the Best Practice detail again. Additionally, as in other OSB SIP details, the air sealing is again in a difficult location and should be relocated to a point where the seams of the panels meet.

There is no sill detail provided on the ThermaSAVE website. We assume that the user would most likely follow a configuration similar to that shown by the SIP Association for OSB SIPS, though this would involve the introduction of wood into the structure. Though the ThermaSAVE panels do not contain any wood, care should still be taken to prevent the introduction of termites into the building as they can affect other wood members and travel through the foam of the ThermaSAVE (and equivalently OSB SIPS) easily without detection.

9 ThermaSAVE Discussion and Recommendations

9.1 Joints

9.1.1 Air / Moisture Sealing

- Because houses built with ThermaSAVE will be really tight, there should be an air sealing detail with intentional ventilation.

- A study should be done to determine the leakage for a standard panel assembly with and without caulking as well as how much ventilation would be needed to supplement in locations such as Afghanistan, where mechanical ventilation will be rare.

- A study should be conducted to determine whether ThermaSAVE panels are reusable if the structure has been air sealed, which is recommended practice. Upon first examination, it seems that the panels would not be reusable, as it would be difficult to take them apart without damaging them. It might be possible to cut the joints, cut off the spline edges, and re-rout the EPS in the new, smaller panels.

9.1.2 Splines

- The routs in both the ThermaSAVE and OSB panels were not perfectly sized. The depth and width of the ThermaSAVE panel routs we received were significantly different than the dimensions of the supplied splines.
    - A study should be done to determine whether the stated reason for this dimensional discrepancy, to pull the panels tightly together, is physically feasible. We hypothesize that it will be difficult to pull the panels together while simultaneously keeping them square and not cracking the edges.

- The splines are supposed to be the same fiber cement material as skin (Lee, et.al).
    - This is to ensure that they expand and contract at the same rate as the panel skin itself. However, on site, people may use OSB splines out of convenience. The implications of this substitution should be studied

further, especially to determine whether the swelling of the OSB spline due to moisture could cause the edge of the panel to crack.

    - We are concerned about Oak Ridge National Laboratory studies that are rumored to show that with prolonged expansion and contraction of the panels, the fiber cement around the screw wears out and leaves the screw with no bearing surface.

- If the panel routs are not deep enough, workers will need to have tools on site to melt out a deeper channel. This has implications for worker health and the construction timeline.

9.2 Moisture Management

9.2.1 Panels as Structure and Skin

- The structural integrity of ThermaSAVE does not seem to be compromised by prolonged exposure to humidity or standing water. However, more tests should be done for confirmation and further understanding of results.
- ThermaSAVE panels do mold in humid conditions, though not as readily or extensively as OSB. This implies that cladding with a drainage plane is necessary.

9.2.2 Window Flashing

- A strategy and set of window flashing details need to be developed in order to avoid pouring water into the window frame from the plane of wall above the window.

    - In order to do this, it seems like the window flashing details will either need to recess the window frame behind wall plane, which we are not sure is feasible with standard windows, or to use a drainage plane exterior to the fiber cement.

    - In the Gulf Coast this is especially important as humidity is high and wind-driven rain will arise in a hurricane.

- Additionally, window installation instructions should be developed that address air sealing of a rough opening around a standard window.

9.2.3 Sill Detail

- Even if no drainage plane is used, a termite flashing detail is still necessary at the sill if any wood is part of the structure. Though there is no harm in termites finding their way through the foam itself, if there is any wood in the structure this pathway must be blocked off.

- Details similar to the SIPs details presented on the SIP Association website may be used for this application.

9.3 Electrical Conduit

- According to the local building codes, electrical runs have to be either 1 ¼” from a nailing surface (interior drywall or ThermaSAVE without drywall) or have to be covered with 16 gauge metal. The routs we found on the ThermaSAVE panel were only ½” from the theoretical nailing surface. A study should be done too look at how this is dealt with in the field. Are builders using metal conduit within the routs? How often do the pre-routed channels line up or not line up?

9.4 Structure

9.4.1 Ridge

- We observed a ridge beam in the ThermaSAVE detail for the ridge. Further details should explain whether this beam is necessary and how the panels meet at the ridge in order to create a durable joint that will not leak.

- What material goes in the 2x routs at the ridge and eave? If this is intended to be wood, studies should be conducted to ensure that expansion and contraction of the wood will not be an issue. If this is not wood, what other materials may be used?

10 Future Work

A number of questions arise from the work we did on this study. Questions for further study include:

- How significant is the air leakage through a standard ThermaSAVE house? A well-sealed ThermaSAVE house?
    - How can you design for this envelope in a location such as Afghanistan where mechanical ventilation will be rare and windows expensive?
- What spline material is optimal?
    - Would OSB or wood expand and contract too much?
    - Would fiber cement wear a groove around the screw and become unstable?
- Since ThermaSAVE molds, how effective and durable is it without cladding or an exterior drainage plane?
- Does the bearing surface of the screws wear out with time? Under what conditions is this most likely to happen? What other methods of fastening panels together are available?
- Field observation studies may be done to get a better understanding of the difficulties that are encountered on the job site and how they may be avoided, as well as understanding the level of skill needed to use this product for future knowledge.

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Figure 1: 2003 U.S. Census Map of Poverty Rates
www.census.gov/PressRelease/www/2005/2003povertyrate_fema_counties.pdf

Figure 2: Shotgun House, New Orleans
www.greatbuildings.com

Figure 3: Creole Cottage, New Orleans
http://bywater.org/Arch/Creole.htm
Note: It is uncommon for Creole cottages to have dormers.

Figure 4: Flooding in New Orleans
http://www.wwltv.com/sharedcontent/breakingnews/slideshow/083005_dmnkatrina/5.html

Figure 5: Image of Wind Damage in Slidell, LA
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Figure 6 Product Evaluation Sheets to Figure 16 Diagonal Load Tests: Alisar Aoun, Corinne Benedek, Anna LaRue

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All " OSB SIPS" Details from
http://www.sips.org/portal/tabid__4977/Default.aspx

All ThermaSAVE Details
www.thermasave.us

13 Appendix A: Contact Information

Federal Emergency Management Agency
500 C Street SW, Washington, D.C. 20472
Disaster Assistance: (800) 621-FEMA
http://www.fema.gov/hazard/hurricane/2005katrina/index.shtm

U.S. Army Corps of Engineers
http://www.usace.army.mil/hurricane.html

Federation of American Scientists
1717 K St., NW, Washington, D.C. 20036
Telephone: (202) 546 – 3300
http://www.fas.org/main/home.jsp

U.S. Department of Housing and Urban Development
451 7th Street, SW, Washington, D.C. 20410-1455
Telephone: (202) 708 – 1112
http://www.hud.gov/

Habitat for Humanity
Partner Service Center
Habitat for Humanity International
121 Habitat Street
Americus, GA 31709 – 3498
Telephone: (229) 924-6935
www.habitat.org

14 Appendix B: Interviews

Conversation with: Building Codes Office, Baton Rouge, 2/14/06, 8:30 a.m. pacific
Name of Person: unknown
Phone number: 225-389-3205

Conversation Notes:

Q: What can you tell me about how you see the Louisiana codes changing?
A: East Baton Rouge parish is using the 2003 ICC codes.
Every parish will make local amendments to the codes.
E Baton Rouge is enforcing amendments to the '03 codes today.
At the end of the year, the state requires every city to revert to the '06 ICC codes.
Q: What would you do if you had a huge source of funding?
A: At the office, they are lacking FUNDs - if they had more money they would have more staff and instead of inspectors doing 30 houses a day, they could do 3.
They are concerned with what inspectors might be missing because they are so rushed to do everything.
Q: I know you don't know exactly what new amendments will be made, but can you give me an example of what you think might change?
A: New amendments include changing the wind load standard from 110 mph to 150 mph, and raising the height that all buildings must be built above ground level.
Q: Anything different going on now? Any special construction?
A: Right now there is metal framing for residential construction going on - yes its more expensive than wood framing but its better in the face of termites, and sustains stronger wind loads.

Conversation with: Home Depot, Baton Rouge, 3/1/06, 11 a.m. pacific
Name of Person: several different employees from different departments inside the store
Phone number: 225-755-1729

Conversation Notes:

A: Customers are buying everything: wall parts, appliances, etc.
Q: But what are they really buying now moreso than before, because of the hurricane?
A: Moisture/mold resistant sheet rock for walls more than regular sheet rock; definitely replacing appliances and walls; buying treated wood.
Q: What else happened at Home Depot?
A: When the hurricane was coming, we had a price freeze, so the prices didn't change.
Q: What other materials are people buying differently or in general?
A: Insulation – it's all the same, fiberglass, occasionally cellulose spray in insulation; sheet rock- anything they can get, even if it's a little more expensive; roofing- people are buying the 30-yr.; and lumber.
Q: Do you know who at Home Depot held the repair workshop around February which brought in thousands of people? No? Can you transfer me to someone who does?

Receiving Department
A: I'm not sure; maybe Angel Clement. Yes, she works for Home Depot.

Conversation with: N.O. Housing Resource Center, 3/1/06, 11 a.m. pacific
Name of Person: Paul Baricos, paul.baricos@gmail.com
Phone number: 504-453-0789

Conversation Notes:

Q: I'd just like to hear anything and everything from you, being in New Orleans, to get a better scope of the situation.
A: Ok. I just got off of a conference call for a symposium that we're planning on April 22, 23 along with the Alliance for Affordable Energy in New Orleans and the New Orleans Neighborhood Development Collaborative. Speakers and workshops will cover energy efficiency, green building, product display, etc. There will be mainstream builders as well as modular housing and steel framing builders. The symposium is for everyone: the public- homeowners, contractors, affordable housing developers, etc.
N.O. people are just waiting to see what buyout reconstruction program using federal money will take place. HUD will be in charge of mitigation money and such. Some sections of the city cannot be rebuilt; they may be raised and turned into parks, etc. A workshop in the symposium will cover how the area can be reused and houses raised.
What's happened is that a lot of the houses have been gutted- down to the studs. People don't know how to rebuild. The FEMA maps should come out in March and they will say who can rebuild. FEMA may require people to raise their homes. Here, we don't have basements; we build on slab foundations, or cinder block piers.
For the first time in La's state legislature, they passed the ICCC. But for the southern half the state, wind sust. of roofs and how constructed will be a little more stringent, but in both instances, now the entire state is subject to the codes! Rural parishes will be given a little more time to enforce the codes.
The law required that if you didn't own your home and were in a certain area, you had to have flood insurance. But some people didn't have flood insurance because FEMA said they weren't in the floodplain- but now they're flooded! In the 9th ward, people lived in "generational homes" so that they weren't required to have flood insurance. There's a $250,000 cap on flood insurance; many of those homes with flood insurance were values in the upper hundreds of thousands of dollars.
Most of the residential reconstruction is ahead of us.
You can contact me again; my email is paul.baricos@gmail.com. Other people who might be helpful are:
Jamie Neville, 504-828-1253, a low-income housing developer who's done steel framing and some modular stuff;
Dan Etheridge, 713-504-5619, a student at the Tulane School of Architecture;
Angela Obyrne, 504-915-5346, an architect? who knows more than me on building materials
Mika Walker, 504-258-1247, at the Alliance for Affordable Energy in N.O.; Mika will probably refer you to Forrest.

Conversation with: Fire Expert from UC Berkeley, 4/3/06, 12:00 p.m. pacific
Name of Person: Prof. Williamson, bradywilliamson@sbcglobal.net
Phone number: 510-527-2248

Conversation Notes:

A: mention of Art Rosenfeld, and a meeting at LBNL last year, in which some of the below information was shown?
- Plastics→
    1. thermoplastics
        a. polystyrene
            i. extruded; DOW makes them in a big factory
            ii. expanded (EPS)
        - melts and turns into a liquid at relatively low T, ~ 200 F
        - cheaper; EPS is cheapest of all; EPS just needs to be transported to site in bead ford, and then expanded via steam
        - EPS alternative for low-cost housing for these reasons
        - Polystyrene safe on outside of building, especially when there's fire proof gypsum board on the inside and proper sealing safeguarding the interior at the windows and other openings
            - but when not proper sealing, and polystyrene begins to melt just outside of a window, and it drips down into the house → HUGE flame results
    2. thermosetting plastics
        - cross-linked
        - i.e. polyurethane
        - better insulators

Polystyrene is not worth it in buildings because of its fire disadvantage
Political pressure is the reason that polystyrene is allowed as a building material
When you sandwich a panel with gypsum on the inside, polystyrene gets out too fast (through the cracks; can't perfectly seal it); gypsum board provides a 15 min rating.
Inside gypsum board, there's a certain number of water molecules for every calcium sulfate molecule; these water molecules keep the temperature relatively low, until they evaporate off; this time period provides the "15 min rating".
Prof. W. has the facility to test how long a building wall system will last; test up to ~ 1800 F.
Tested EPS on outside of concrete: gypsum wall dehydrated in 15 min, then he had to turn the burners off (which were supplying the flame and high T) because the polystyrene was dominating the flame and caused the T to shoot over 2000 F; because the concrete was encapsulated, it stored a lot of moisture, which dramatically evaporated? once the fire reached it.

In a fire, polystyrene is like bringing in a hydrocarbon fire, but this industry very politically active; they push their product; claim 0-flame in a wood test that is over 60 yrs old; this test is conducted in a duct and shows no spreading as under a ceiling of the material (although there would be 100% spreading on a floor!)
In N.O., get board stock made from polyurethane instead of polystyrene (not so easily available in Afghanistan).
Polystyrene is like gasoline in solid form.
One really great product is made by DOW, it’s foil-faced, fiber reinforced, has great fire performance, but don’t want foil on the interior of peoples buildings.
Q: Can’t you just add another interior over the foil and use this?
A: you can! But it’s pricey
Q: Why didn’t the producers use polyurethane instead of polystyrene, especially if you told them about the fire performance?
A: because polystyrene is cheaper; they have bad data; because they didn’t want to change..etc.
I’ll send you a paper “Role of Interior Finishes on Fire”? on all these different kinds of fire tests; it has pics. It talks about interior finishes of polystyrene and polyurethane, but doesn’t distinguish between the two. I’ll ask around and see where you can get more info on that.
Here is the name and number of an engineer in Florida, a consultant to PEMA (poly…. Association). She is very knowledgeable about building codes, fire safety, and can tell you a lot about polystyrene and polyurethane. She might even know some people in N.O.
Loraine Ross (727) –397 –4409 {this number doesn’t work – A.A.}

Q: What is the name of the fire tests that you conducted at LBNL?
A: ASTM E 119 Fire Resistance Test; it tests fire spread through a wall; it shows the weakness of PS. The paper I sent to you has to do with flame spread.
Q: Did you test EPS between cementitious boards?
A: No. just between gypsum boards. Gypsum gives about 15 min protection, and cement board would probably give about the same.
In a serious fire, neither will protect. In a small fire, might protect.
A: Please email me, call me, set up an appointment with me. Would love to meet with you guys, and show you the power-point presentations I have on this, and everything else!

15 Appendix C: The Materials Matrices

Studs	Metal	Pressure treated wood	Western Douglas Fir	Machine Stress Rated	Southern Pine
HEALTH	☐	⊠	☐	☐	☐
VOC Content		⊠			
Non-Toxic	☐		☐	☐	☐
Worker Health		⊠	☐	☐	☐
Fire Safety		☐	☐	☐	☐
SAFETY		▣	▣	▣	☐
Material Strength		☐	☐	▣	☐
Durability		▣	☐		☐
Structural Stability					
Ease of Disposal		☐	▣	▣	▣
COST	⊠	☐	☐	☐	☐
Unit Cost					
Do It Yourself?	✗	✓	✓	✓	✓
Easy to Use?	✗	✓	✓	✓	✓
Equipment?	✓	✓	✗	✗	✗
Contractor?	✓	✗	✗	✗	✗
Maintenance		▣	☐	☐	☐
Thermal Performance	×	☐	☐	☐	☐
LOCAL	■	▣	☐	☐	☐
Performance After Flood	■		☐	☐	☐
Permits Drying		☐	☐	☐	☐
Mold Resistance	■	▣	☐	☐	☐
Termite Resistance	■	▣	☐	☐	☐
Local Acceptance	☐	▣	▣	▣	▣
GREEN	▣	☐	☐	▣	▣
Recycled Content	■	☐	☐	☐	☐
Renewable Material?	✗	✓	✓	✓	✓
Resource-Efficiency Potential	✓	✓	✓	✓	✓
Locally Manufactured?		→	✗		✓

Sheathing	Plywood	OSB	DensGlass Gold ®
HEALTH	☐	☐	☐
VOC Content	☐	⊠	→
Non-Toxic	☐	☐	
Worker Health	☐	☐	⊠
Fire Safety	☐	☐	■
SAFETY	☐	☐	☐
Material Strength	☐	☐	☐
Durability	☐	☐	▣
Structural Stability			
Ease of Disposal	☐	☐	☐
COST	⊠	☐	
Unit Cost	[illegible]	[illegible]	→
Do It Yourself?	✓	✓	✓
Easy to Use?	✓	✓	✓
Equipment?	✗	✗	✗
Contractor?	✗	✗	✗
Maintenance			
Thermal Performance			
LOCAL	☐	☐	☐
Performance After Flood	☐	⊠	⊠
Permits Drying	☐	⊠	⊠
Mold Resistance	☐	☐	▣
Termite Resistance	☐	☐	→
Local Acceptance	▣	▣	▣
GREEN	▣	▣	☐
Recycled Content	⊠	☐	☐
Renewable Material?	✓	✓	
Resource-Efficiency Potential	✓	✓	✓
Locally Manufactured?	✓	✓	

Roofing

	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do it Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
Asphalt Shingles	☐			×	☐	⊠	×	▣		×	⊠	$	N	N	Y		×	×	☐		☐	×		☐	⊠	☐	N	N	Y
SBS-modified asphalt shingles	☐			×	☐	⊠	×	▣		×	⊠	$	N	N	Y		×	×	☐		☐	×		☐	⊠	☐	N	N	
Metal roof panel	☐			×	☐	☐	×	▣		▣	☐	$$	Y	Y	N		☐	☐	⊠		×	▣			▣	▣	Y	Y	Y
Standing Seam metal	☐			×	☐	▣	×	■		▣	☐	$$	Y	Y	N		☐	☐	⊠		×	▣			▣	▣	Y	Y	Y
Tital Cool Roof Coatings	☐			×	☐	☐		☐			?	?	N		Y			■							☐	☐	N	Y	

Company Name	Product
CertainTeed Corp.	XT-30 Impact Resistant
Atlas Roofing Corporation	StormMaster LM
ATAS International, Inc	ScanRoof®
McElroy Metal, Inc	MasterLok-90
Custom-Bilt Metals Inc.	TITAN Cool Roof

Siding

	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do it Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
Hardiplank ® Lap Siding	⊠	⊠	×*	⊠	☐	▣	▣	☐	▣	☐	☐	$	Y		N	N	▣		▣	▣	☐	▣	▣		▣		Y	Y	Y
Cypress Siding	☐	☐	☐	☐	⊠	☐	▣	☐	☐	☐	⊠	$$	Y		N	N	☐		⊠	⊠	☐	⊠	⊠	☐	☐		Y	N	Y
Vinyl Siding	⊠	☐	☐	⊠	×	☐	▣	☐	☐	⊠	☐	$	Y		N	N	▣		☐	▣	⊠	▣	▣		⊠		N	N	Y
Aluminum Siding	☐	☐	☐	☐	⊠	☐	▣	☐	☐	☐	☐	$	Y		N	N	▣		☐	▣	⊠	▣	▣		▣		Y	Y	Y
Stucco	☐	☐	☐	☐	☐	⊠	⊠	⊠		☐	☐	$	Y		N	N	☐		☐	▣	▣	☐	⊠	⊠	▣		Y	Y	Y
EIFS	☐	☐	☐	☐	⊠	⊠	⊠	⊠	⊠	⊠	⊠	$$	N		N	Y	⊠	▣	⊠	⊠	⊠	☐	⊠	⊠	×		N	N	Y

* Cedar Stains highly toxic

Company Name	Product Name
James Hardie International Finance B.V.	Hardiplank ® Lap Siding
CypressSiding.com ™	Cypress Siding
CertainTeed Corp.	Vinyl Siding
Alcoa Home Exteriors	Aluminum Siding
{Generic}	Stucco
{Generic}	EIFS

ICFs	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do It Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
Quad-lock® Quad-lock for Walls	□			□	□	▣	▣	▣	▣	□	⊠	$$	N	N	Y	Y	□	▣	□	□	Y	□	□	□	⊠		N		N
Polysteel PS-4000 Flat Wall Form	□			□	□	▣	▣	▣	▣	□	⊠	$$	N	N	Y	Y	□	▣	□	□	Y	□	□	□	⊠		N		N
Styrofoam T-Mass Technology	□			□	□	▣	■	▣	▣	□	⊠	$$	N	N	Y	Y	□	▣	▣	▣	Y	□	▣		⊠		N		N

Company Name	Product Name
Quad-lock®	Quad-lock for Walls
PolySteel®	PS-4000 Flat Wall Form
The Dow Chemical Company	Styrofoam T-Mass Technology

Panel Construction	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do It Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
ThermaSAVE	⊠			×	□		?	?		□	□	?	N		Y	Y		▣					□		□	N	N	Y	Y
General Panels	⊠			×	□	□	□	▣	□	□	□	$	N	Y	Y	Y		▣	□			□	□	□			Y	Y	Y
R-Control SIP	⊠	□	×	×	□	□	□		□	□	□	?	N	Y	Y	Y		▣	□			□	▣	□				Y	
Thermocore™ SIP	□	□	□	×	⊠	□	□		□	□	⊠	$$	N		Y	Y		■	□			□	□	□				Y	

ThermaSAVE, ThermaSAVE Building Systems
General Panels, General Panel
R-Control SIP, R-Control Building Systems
Thermocore™ SIP, Thermocore™ Panel Systems

Drainage

	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do It Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
Fortifiber Building Systems Group ®	☐			☐	☐	☐	☐	☐		☐	☐	$	Y	N	N	N		☐	☐	☐	☐	☐			×	☐	N	N	N
15# Felt Paper, Asfelt	☒	☒	☐	☒	☒			?		☐	☐	$	Y	N	N	N		☐	☐	☐	☐	☐	☐	☐		☐	N	N	N
DuPont™ Tyvek® HomeWrap®	☐	?	?	☒	☒			?		☐	☒	$$	Y	N	N	N		▣	☐	☐	☐	☐	☐	☐	?	☐	?	?	?
BBA Fiberweb™, Typar HouseWrap	☐			☐	☐	▣	▣	▣		☐	☐	$$	Y	N	N	N		▣	×	×	☐	×			☐	☐	N	Y	Y

Company Name	Product Name
Fortifiber Building Systems Group ®	Two-Ply Super Jumpo Tex® 60 Min
BBA Fiberweb™	Typar HouseWrap

Gypsum Board

	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do It Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
DensArmor®	☐	☐	☐	☐	☐	☐	▣	☐		☐	☐	$	Y	Y	N	N	☐	▣	▣	☒	☐	■		☐	☐	?	N	Y	?
ToughRock®	☐	☐	☐	☐	☐	▣	▣	▣		☐	☐	$	Y	Y	N	N	☐	☐	☐	☒	☐	☐		☐	☐	▣	N	Y	?
FIBEROCK® AQUA-TOUGH™	☐	☐	☐	☐	☐	■	▣	■		☐	☐	?	Y	N	N	N	▣	?	▣	☒	☐	■		☒	▣	■	N	Y	N
Hardibacker®	☐	☒	☐	☐	☐	■	▣	■		☐	☐	$$	Y	N	N	N	▣	☐	▣	☐	☒	■		☒	☐	?	N	Y	?

Insulation

Insulation	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do It Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
Propink High Density	☐	▣	?	☐	☒	?		?		☐	☐	?	Y	Y	N	N		▣	☐	☐		☐		☐	☐	▣	N		
Foamular	☐	▣	☐	☐	×	▣		▣		☐	▣	$	Y	Y	N	N		■	☐	▣	☒	▣		☐	☐	▣	N	Y	
Guardian Fiberglass Insulation	☐	▣	☐	☐	?	?		?		☐	☐		Y	Y	N	N		☐	?	?		?		☐	☐	☐	N	Y	N
ComfortTherm	▣	▣	☐	▣	☐	☐		☐		☐	☐	?	Y	Y	N	N		☐	☐	☐		▣		☐	☐	▣	N	Y	
MR Faced Batts	☐	▣	☒	☐	☐	☐		☐		☐	?		?	?	?	?		?	☐	☐	☐	▣		☐	☐	▣	N	Y	
Climate Pro	▣	▣	☐	☐	☐	☐		☐		☐	☒		N	N	Y	Y		☒	☐	☐		?		☐	☐	▣	N	?	
Cocoon Insulation	☐	▣	☐	☐	☒	☐		☐		☐	☒	$	Y	N	Y	N		☐	☒	×		☐		☒	▣	■	Y	Y	
Icynene	?	▣	?	?	?	▣		▣		☐	☒	$	N	N	Y	Y		☐	▣	☐	▣	▣	▣	?	☐	☐	N	Y	
Cotton Insulation	■	■	?	■	☐	?		?		☐	☐		Y	Y	N	N		☐	?	?		?		☒	▣	■	Y	Y	
Dow Blue Board	☒	?	☒	☒	×	▣		▣		☐	?		?	?	?	?		▣	☐	?		▣		☐	?	☐	N	?	

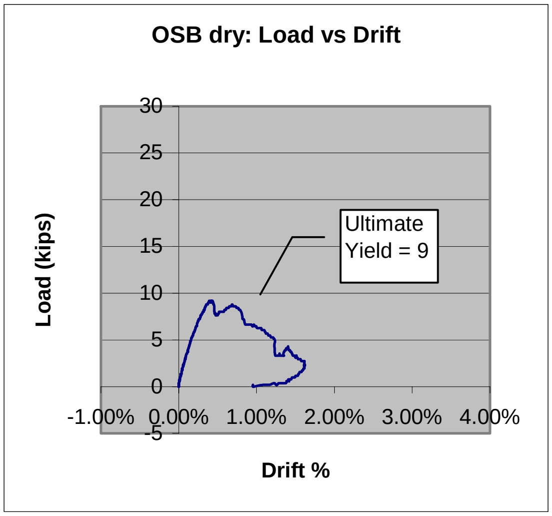
Concrete & Masonry*

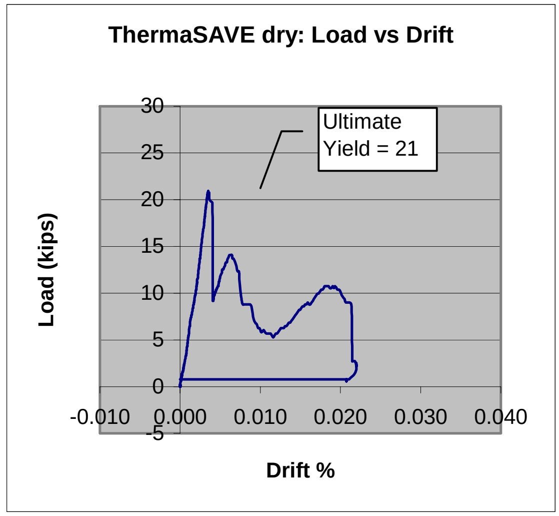
Concrete & Masonry*	HEALTH	VOC Content	Non-Toxic	Worker Health	Fire Safety	SAFETY	Material Strength	Durability	Structural Stability	Ease of Disposal	COST	Unit Cost	Do It Yourself?	Easy to Use?	Equipment?	Contractor?	Maintenance	Thermal Performance	LOCAL	Performance After Flood	Permits Drying	Mold Resistance	Termite Resistance	Local Acceptance	GREEN	Recycled Content	Renewable Material?	Resource-Efficiency Potential	Locally Manufactured?
Concrete traditional	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	$	N	N	Y	Y	N	☐	☐	☐	☐	☐		☐	☐	☐	N	N	Y
Concrete with fly ash	☐	☐	☐	☐	☐	▣	▣	▣	▣	☐	☐	$	N	N	Y	Y	N	☐	☒	☐	☐	☐		☒	▣	▣	N	Y	Y
Brick	☐	☐	☐	☐	☐	☐	☒	☐	☒	☐	☐	$	N	N	N	Y	N	☐	☐	☐	☐	☐		☐	☐	☒	N	Y	?
Cinder Blocks / CMU	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	▣	$	N	N	N	N	N	☐	☒	☐	☐	☐		☒	☐	▣	N	Y	Y
AAC Concrete	☐	☐	☐	☐	☐	☐	☒	☒	☒	☐	☐	$$	N	N	N	Y	N	▣	☒	☐	☐	☐		☒	☐	☒	N	Y	Y
Concrete with Ductal®	☐	☐	☐	☐	☐	▣	▣	☐	▣	☐	☐	?	N	N	Y	Y	N	☐	☒	☐	☐	☐		☒	☐	☐	N	N	?

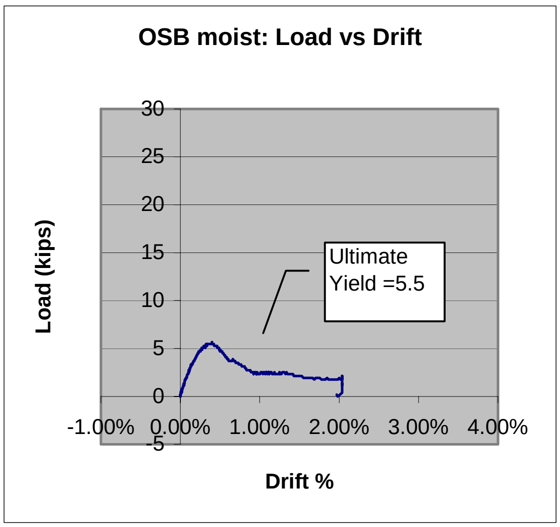
16 Appendix D: Contact Information for Product Manufacturers

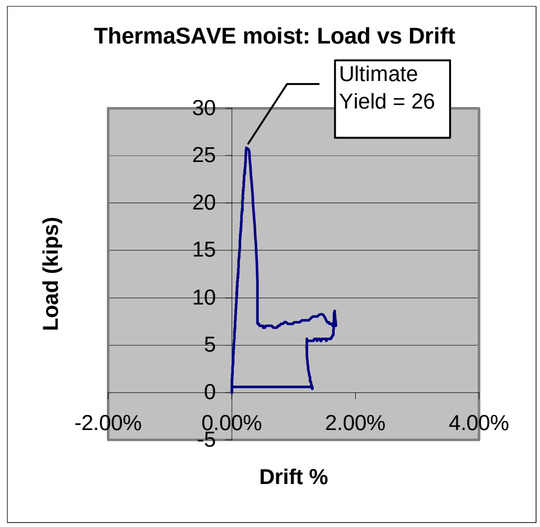
Georgia-Pacific Corporation	www.gp.com
CertainTeed Corporation	www.certainteed.com
Atlas Roofing Corporation	www.atlasroofing.com
ATAS International Inc.	www.atas.com
McElroy Metal, Inc.	www.mcelroymetal.com
Custom-Bilt Metals, Inc.	www.custombiltmetals.com
James Hardie International	www.jameshardie.com
Cypress Siding	www.cypresssiding.com
Alcoa Home Exteriors	www.alcoa.com
Quad-Lock Building Systems	www.quadlock.com
American PolySteel Forms	www.polysteel.com
Dow Building Products	www.dow.com/buildingproducts
ThermaSAVE Building Systems	www.thermasave.us
General Panel Corp.	www.sipsproducts.com
R-Control Building Systems	www.r-control.com
Thermocore Panel Systems	www.thermocore.com
Fortifiber Corporation	www.fortifiber.com
BBA Fiberweb	www.bbafiberweb.com
USG Resources	www.usg.com
Johns Manville	www.jm.com
Guardian Fiberglass	www.guardianfiberglass.com
US Greenfiber	www.greenstone.com
Hebel USA	www.hebel-usa.com
Ductal	www.ductal.com

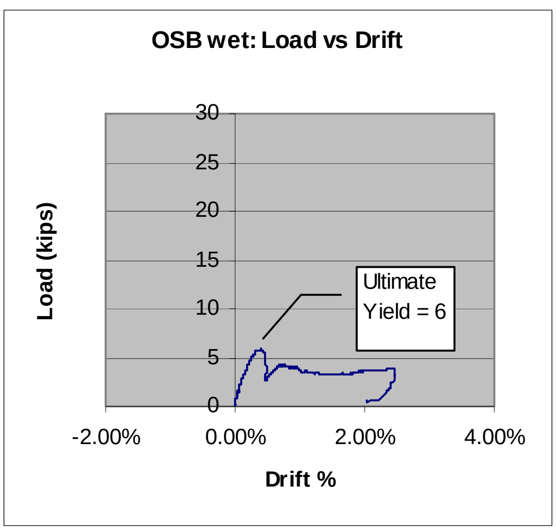
17 Appendix E: Load vs. Drift Plots

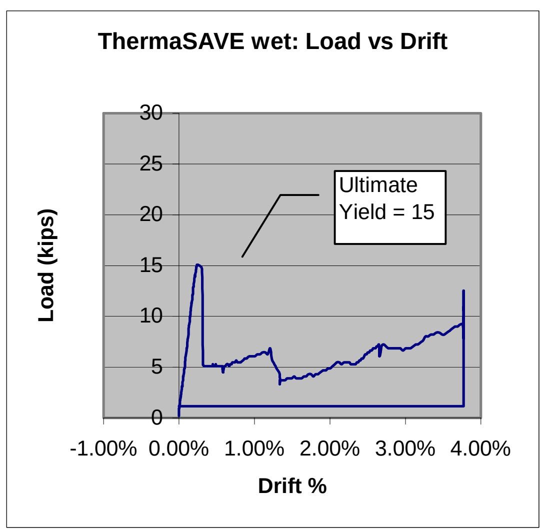












18 Appendix F: Evaluation of Pre-Test Panels Condition

Thermasave Panels
-Seems to be layers, paper coating
-All conduit is flush with sheathing, about an inch deep and an inch and a half wide

T-1
Routs
-Opposite vertical sides for splines
-Top and bottom have no routs
Conduit
-No conduit
Sheathing
-Some paint
-Scuffs all around
Other
-Horizontal seam through middle of foam

T-2
Routs
-Opposite vertical routs for splines
-Bottom is routed for a 2x4
Conduit
-No conduit
Sheathing
-Big crack on upper front left corner
-Dent on upper front center
-Back left supper corner separating

T-3
Routs
-Opposite vertical routs for splines
-Top and bottom flush
Conduit
-Horizontal conduit

-Flush with front and centered vertically
Sheathing
-Large crack in front lower left
-Dent in upper left front
-Dent in bottom front center
-Crack in front bottom right corner

T-4
Routs
-Opposite vertical routs for splines
-Top and bottom flush
Conduit
-No conduit

Sheathing
-Dent in front upper left corner
-Dent in front bottom left corner

OSB Panels
-All conduit is flush with sheathing, about an inch deep and an inch and a half wide

OSB-1
Routs
-Opposite vertical routs for splines
-Top has routs for splines
-Bottom is routed for a 2x4
Conduit

-Vertical conduit flush with front

OSB-2
Routs
-Opposite vertical routs for splines
-Top has routs for splines
-Bottom is routed for a 2x4
Conduit
-Vertical conduit flush with front
Other
-Broken foam piece in top

OSB-3
Routs
-Opposite vertical routs for splines
-Top has routs for splines
-Bottom is routed for a 2x4
Conduit
-Vertical conduit flush with front
Sheathing
-Dent in upper front right corner

OSB-4
Routs
-Opposite vertical routs for splines
-Top has routs for splines
-Bottom is routed for a 2x4
Conduit
-Vertical conduit flush with front